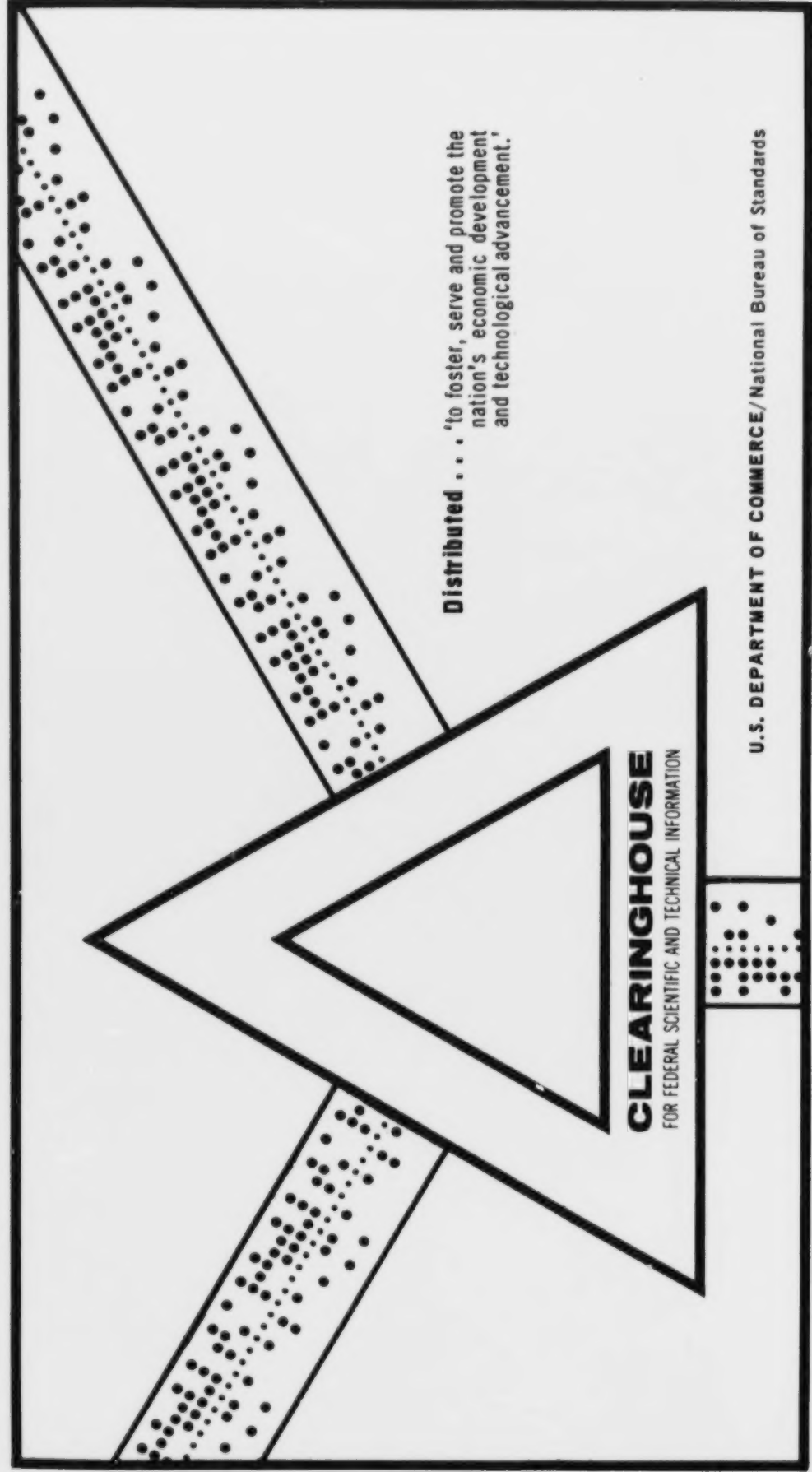


PB 187 301

LAND RECLAMATION PROJECT

Metropolitan Sanitary District of Greater Chicago
Chicago, Illinois

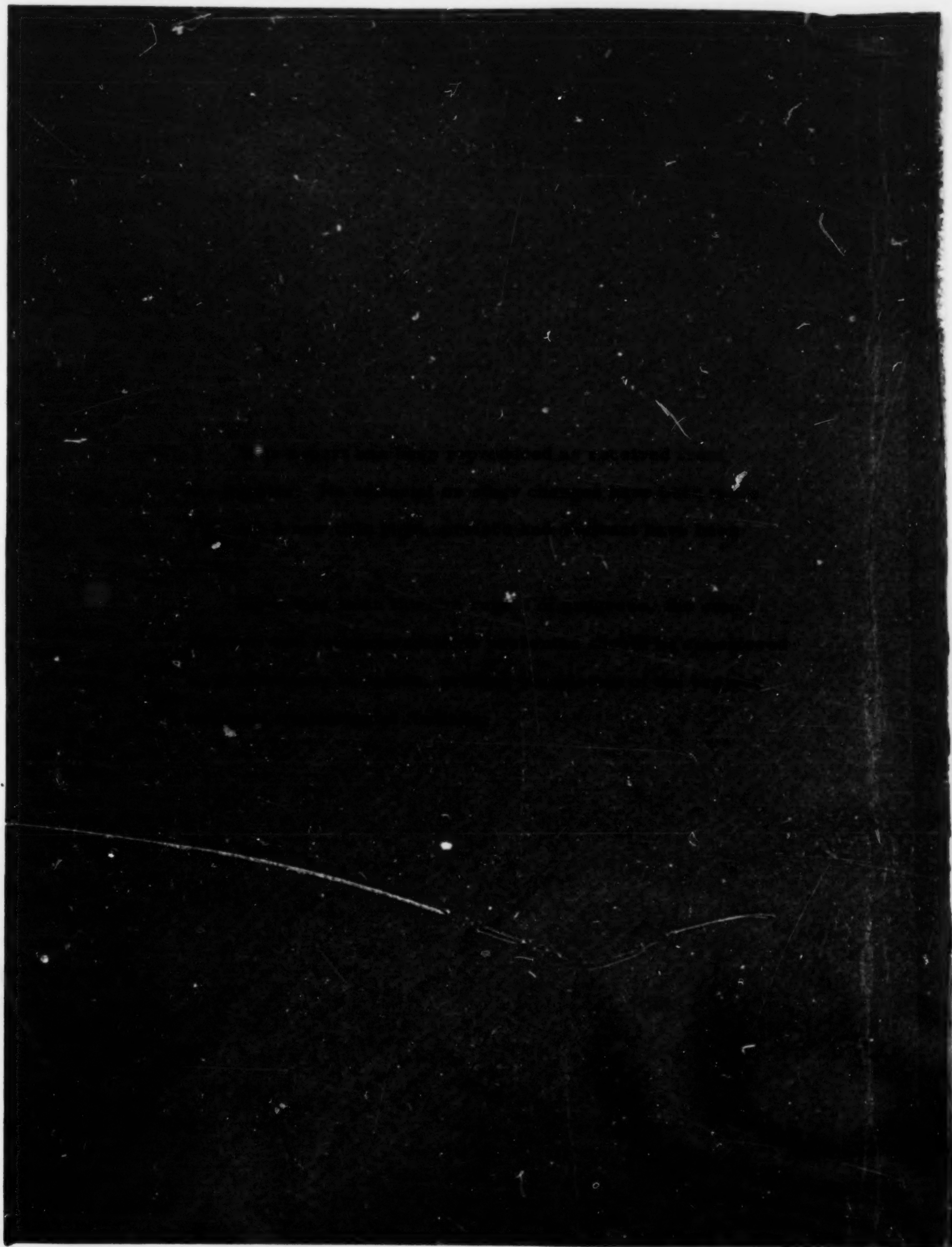
1968



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Metropolitan Sanitary District of Greater
Chicago, Ill.

PB-187301

LAND RECLAMATION PROJECT

An Interim Report

Prepared by Harza Engineering Company
Assisted by Bauer Engineering, Inc.
under Grant No. DO-UI-00080

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service
Environmental Control Administration
Solid Wastes Program
Cincinnati
1968

PB-187301

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**U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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Solid Wastes Program
Cincinnati
1968**

PREFACE

An estimated 800 million pounds of solid wastes of all types are produced in the United States every day. What to do with these solid wastes, how to dispose of them without needlessly endangering public health and welfare, and how to recover and reuse valuable materials now "thrown away" are among the most challenging and perplexing of current national problems. Because of lack of suitable planning, interest, and public understanding, these problems have reached such proportions that nationwide attention is demanded and action for the development of adequate solutions must be taken.

Intensified action concerning these problems was made possible by the Solid Waste Disposal Act, Title II of Public Law 89-272, which was signed by the President on October 20, 1965. This legislation directs the Secretary of the Department of Health, Education, and Welfare to initiate, encourage, and support a national program aimed at discovering and evaluating better methods of coping with the solid waste problem.

The Secretary is authorized (1) to conduct and support research on the nature and scope of the problem, on methods of more safely and efficiently collecting and disposing of solid wastes, and on techniques for recovering from solid wastes potentially valuable

materials and energy; (2) to provide training and financial and technical assistance to local and State agencies so that they can survey their needs in the solid waste area and plan for the development and staffing of programs capable of meeting those needs now and in the years to come; and, (3) to encourage and support projects that may demonstrate new and improved methods of solid waste collection, handling, and disposal.

To carry out these responsibilities, the Solid Wastes Program was established. Among the responsibilities with which the Program is charged is that of providing grant support for demonstrations relating to the development and application of new and improved methods of solid waste collection, storage, processing and ultimate disposal; and also for studies and investigations that may lead to a demonstration of improved disposal practices, or may provide solutions for regional or national solid waste disposal problems. Associated with this is the responsibility of collecting and making available by appropriate means the results of, and other information pertaining to, such federally supported demonstrations, studies and investigations.

Accordingly this report has been reproduced to disseminate as widely as possible the latest available information and findings of a project that has received grant support from the Solid Wastes Program. It is hoped that it will provide those working in this field with useful information that will be of assistance in developing approaches to the solutions of their solid waste disposal problems.

This is an interim report of project progress, and additional work is currently underway to complete the project as identified in the abstract included herein. Additional progress reports, when received, will also be made available by the Solid Wastes Program for widespread distribution and use. The final report will be issued as a Public Health Service publication.

-- RICHARD D. VAUGHAN

Chief, Solid Wastes Program

ABSTRACT OF DEMONSTRATION GRANT NO. DO1-UI-00080

TITLE: Agricultural Benefits and Environmental Changes Resulting from the Use of Digested Sewage Sludge on Field Crops, and Development of Economic and Physical Characteristics Criteria for Use in Selecting Disposal Sites

GRANTEE: The Metropolitan Sanitary District of Greater Chicago

Project Director: Frank E. Dalton, Acting Chief Engineer
The Metropolitan Sanitary District of Greater Chicago
100 East Erie Street
Chicago, Illinois 60611

DATE PROJECT STARTED: March 1, 1967

DATE PROJECT ENDS: February 28, 1970

OBJECTIVES: *The purpose of the report is* To determine the agricultural benefits and environmental changes resulting from the use of digested sewage sludge on field crops, and to develop the criteria related to economic and physical characteristics for use in selecting disposal sites.

PROCEDURES: The Agronomy Department of the University of Illinois will conduct laboratory, greenhouse, and field investigations to determine:

1) the most practical amount, frequency, economical method and time for applying digested sludge on crop land; 2) the probability of contaminating surface water and groundwater aquifers with pathogens and molecular organic and inorganic ions; 3) the changes in the soil related to such physical and chemical characteristics that might be expected from frequent heavy applications of digested sludge; and 4) the crops and cropping systems that will provide maximum absorption of certain essential and non-essential elements supplied to the soil by digested sludge applications.

Concurrently with the above, the Harza Engineering Company, Chicago, Illinois, will investigate possible disposal sites for the District's digested sludge, and will recommend the site or sites most suitable for this purpose, and evaluate the routes and means for conveyance of sludge to the selected site or sites.

SUMMARY LETTER

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APPENDICES

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HARZA ENGINEERING COMPANY

CONSULTING ENGINEERS

RIVER PROJECTS

400 WEST MADISON STREET

CHICAGO, ILLINOIS 60606

CABLE ADDRESS HARZENG CHICAGO

TELEPHONE RANDOLPH 6-3451

October 3, 1967

Mr. Vinton W. Bacon
General Superintendent
Metropolitan Sanitary District
of Greater Chicago
100 East Erie Street
Chicago, Illinois 60611

Subject: Land Reclamation Project

Dear Mr. Bacon:

We are pleased to submit this summary report on the site and route selection studies for the utilization of digested sludge for land reclamation. The studies have been conducted in accordance with your Purchase Order No. A95123 of April 1, 1967. The investigation program was supported, in part, by a grant from the Public Health Service, United States Department of Health, Education, and Welfare.

Prior to initiation of these investigations, the Sanitary District concluded from its own studies that the concept of land reclamation by use of digested sludge is feasible and economically justified. Our investigations, therefore, have been limited to selection of the sites best suited for the land reclamation concept and of the transportation methods and routes which could best serve the selected sites.

Summary of Recommended Program

We recommend a staged program of land reclamation by use of digested sludge. This program is designed to accommodate the gradual increase in sludge production and the phasing out of present methods of sludge disposal, as shown on Exhibit A. The site locations recommended for sludge utilization are shown on Exhibits B and C. Details of the staged program are shown graphically on Exhibit D.

Mr. Vinton W. Bacon

October 3, 1967

The recommended program includes the following:

Phase 1 - Initiation of a sludge utilization experimental program for late 1967, on a small plot at the West-Southwest Plant.

Phase 2 - Acquisition immediately of a 1700-acre site in South-Cook County, south of Tinley Park, on which operations would be initiated in 1968. Sludge utilization at this site would increase from about 30 tons of dry solids per day in 1968 to 220 tons per day in 1971.

Phase 2C - Development during the period 1968 through 1971 of cooperative sites with other organizations, for purposes of demonstrating benefits and possibly obtaining substantial areas for sludge utilization in future years.

Phase 3 - Acquisition of a 21,500-acre site at Essex, south of the Kankakee River. This site would be designed to utilize beneficially the forecasted sludge production of the Sanitary District in the year 2015. The Essex site is composed of sandy soils which now have limited agricultural production. Sludge would be applied, which with supplemental irrigation, would raise crop production and agricultural income by about \$580,000 per year.

The program recommended above is not dependent on developing the co-operation under Phase 2C. The successful accomplishment of Phase 2C would pass on the benefits of sludge utilization to other organizations, primarily public, and would demonstrate these benefits to the general public. It also could defer the necessity of reaching full sludge utilization on the Essex site at an early date and would give greater flexibility in the rates of sludge application in later stages.

Description of Recommended Phases of Program

Phase 1

Phase 1 will consist of initiation at the earliest possible date of a limited-scale program on test plots at the West-Southwest Plant. The purpose

October 3, 1967

of this program is to (a) apply and measure the maximum amount of sludge that can be applied on a grass cover without causing serious problems; (b) observe and record the operating performance of the sprinkler nozzles and associated irrigation equipment; and (c) observe and record environmental conditions such as odor and spray drift, together with concurrent meteorological conditions. The cost of the equipment for this program is estimated to be about \$12,000.

Phase 2

The objective of the Phase 2 site is to provide an area in Cook County on which full-scale sludge utilization can be initiated at a very early date, with assurances that an application rate of 230 dry tons per day can be reached by 1970. This will provide a means of utilization of the sludge and Zimpro ash presently being deposited in lagoons, so that the use of lagoons could be discontinued by 1970. Also, it will provide an opportunity to test different rates of sludge application and demonstrate the benefits from sludge utilization, prior to the time the larger Phase 3 site is placed in operation.

We have made a map study and field reconnaissance of potential open-areas in Cook County for the Phase 2 site. We consider that sandy soils are more adaptable to sludge utilization because of the greater susceptibility to an upgrading of the character of agricultural development; however, we have been unable to find any sandy soils in Cook County which would be available for such a project. Although sandy soils would be better, we foresee no insurmountable problems in the use of a site with fine-textured soils.

Exhibit B shows the alternative undeveloped land areas which have been investigated. All of these sites have fine-textured soils, are presently rural in character, and have only limited housing on the sites. There are no apparent advantages of one site over the other in cost or in types of soil.

We recommend the immediate acquisition of land for the site south of Tinley Park, for the following reasons:

- (a) The topography is the most favorable -- the land slopes are generally flatter, with the exception of one minor escarpment.

Mr. Vinton W. Bacon

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- (b) The area is bordered by the Forest Preserve on the east, which favors the maintenance of adjoining land in open space.
- (c) The size of the area, approximately 1700 acres, fits into a sludge loading program of variable intensity which will allow utilization by the year 1970 of all the digested sludge presently being disposed of in the lagoons.

Experience will be desirable in the practical application of sludge to agricultural lands before the Phase 3 site is developed. For this reason, we recommend that the Tinley Park site be developed by using a range of rates of sludge applications. To accommodate the earliest possible utilization of the sludge presently deposited in the lagoons, an accelerated application rate will be used during the early years of operation. Loading rates will vary from 10 to possibly as much as 300 tons per acre per year.

Since the Tinley Park site is designed for accelerated loading in the initial years of operation, it will not be possible after 1971 to take care of the production presently deposited in the lagoons without additional sites for sludge utilization. It is for this reason that either Phase 2C or Phase 3 must be ready for operation in 1972. Exhibit D shows that, in 1972, additional sites will be needed to utilize future sludge production.

We recommend that sludge be transported to the Tinley Park site by truck, at least during the initial year or two of operation. The use of trucks in the early years of operation would give more flexibility for a decision on the ultimate method of transportation.

The cost of the Tinley Park site is estimated to be as follows:

Land Purchase	\$3,880,000
Agricultural Development	450,000
Loading Facilities	730,000
Engineering and Administration	<u>180,000</u>
Total	\$5,240,000

On the basis of amortization of all capital costs over a 50-year period, operations on this site will result in disposal costs of about \$25 per

Mr. Vinton W. Bacon

October 3, 1967

ton, as compared to about \$45 per ton, which is the most economical alternative method estimated by the Sanitary District. Despite the relatively high costs of land for the Phase 2 site, the cost will be significantly less than any of the alternative methods.

We recommend that land purchases be made under arrangements whereby the present owner could, if desired, lease back the land for agricultural purposes, under operational controls maintained by the Sanitary District.

Phase 2C

This phase of the program consists of cooperative arrangements with various public and private organizations, in which sludge would be applied and utilized on lands remaining in present ownership. The possibility of such cooperative programs depends on a demonstration of the benefits to the present owner.

Discussions have been held with a number of organizations concerning such a cooperative approach. The reception has varied from reluctance to cautious interest. In all instances, it has been stated that the organization would be interested in participating initially only on an experimental basis, and then only if it could be demonstrated that the experimental applications would not be detrimental to the primary purpose of the organization.

The organizations contacted include the State Department of Conservation, the State Highway Department, the Cook County Forest Preserve District, the Joliet Arsenal, the owners of strip mines (including sportmen's clubs) and private farmers. Other possibilities which might be considered include O'Hare Field, County Highway Departments, and potential landfills along Lake Michigan. The areas involved range from 1000 acres to as much as 5000 acres.

We strongly recommend that steps be taken at an early date to develop cooperative arrangements with one or more of the organizations. Acceptance by these organizations on an experimental basis, and later on a continuing basis, would go far toward public acceptance of sludge utilization. For this reason, it would be highly desirable to have some cooperative programs underway prior to the time that the Phase 3 project is initiated.

Mr. Vinton W. Bacon

October 3, 1967

The initiation of Phase 2C cooperative projects would also provide considerable flexibility to the sludge utilization program. The rate of application at the Phase 3 site could be varied, if needed, from the rate of 20 tons per acre annually, established by you as a criterion for the study. Also, the development of cooperative sites under Phase 2C would provide for a continuation of utilization of the sludge presently deposited in the lagoons in the event there is a delay in the Phase 3 site development.

Phase 3

On the basis of a continuous loading rate of 20 dry tons per acre per year, it will be necessary to have a gross area of 21,500 acres. This will provide a net area available for sludge utilization (after deducting roads and farmsteads) of 19,400 acres, which will accommodate the sludge production anticipated in the year 2015 for the West-Southwest, Calumet, and North Side Treatment Plants.

Our investigation leads us to believe that the loading rate of 20 tons per acre annually may be difficult to attain on a continuous basis. However, this observation is not conclusive -- a final conclusion cannot be reached until the results of the studies of the University of Illinois are available. If a lower loading rate is necessary, a greater amount of land will be needed, but there is sufficient flexibility in the proposed program of sludge utilization to allow later adjustments. The loading rate of 20 tons per acre annually is considered to be a valid basis for comparison of alternative sites.

We have investigated all potential 21,500 acre sites in the area south of the Kankakee River in which sandy soils predominate. We have also investigated two potential sites north of the Kankakee River in fine-textured soils. Our initial investigation of these possible sites was narrowed down to the four sites shown on Exhibit C. Of these, three (Coal City, St. Anne, and Essex) are in sandy soils and one (Andres) is in fine-textured soils.

Our studies reveal that irrigation will be required to maintain a satisfactory agricultural operation and realize the potential for upgrading of sandy soils. Therefore, we have included irrigation in the cost and benefit comparisons of the sandy-soil sites. Irrigation will not be essential for maintenance of successful agriculture with sludge application at the fine-textured soil site and has not been included in the comparison.

Mr. Vinton W. Bacon

October 3, 1967

The results we have obtained are shown in Table A. It is apparent from the comparison that the Coal City and St. Anne sites are significantly higher in cost, with lower benefits, than the Essex Site. There are no significant technical or intangible advantages of either the Coal City or the St. Anne location to counteract the cost and benefit disadvantages; therefore, the selection can be narrowed down to a comparison of the Essex and Andres sites. A comparison of the advantages and disadvantages of the Essex and Andres sites is given in Table B.

We recommend that the Essex site be selected for land acquisition. By far the most important consideration leading to this recommendation is the upgrading of crop production capabilities of the Essex site and, therefore, the substantial benefits it will give to the farmers and merchants of the area. Because of this we anticipate a better acceptance by the local interests. In contrast to this, we anticipate little or no local economic impact through use of the Andres site. Other advantages and disadvantages of the two sites seem to about offset each other.

The preliminary cost of development of the Essex site is estimated to be as follows:

Land Purchase	\$ 9,000,000
Transportation System	18,000,000
Site Development	<u>20,000,000</u>
Total	\$47,000,000

Land purchase costs have been based on estimates of current market value and do not reflect any assessment of possible speculation as a result of this project.

We recommend that land acquisition be carried out on the basis of giving the present owners the opportunity of leasing the land, under favorable terms, for operation in accordance with methods of sludge application that will be controlled by the District. This is the same procedure we recommend for the Tinley Park site. This method will provide the least disruption to the residents of the area and should gain the most widespread local acceptance. It also will provide competent farmers to carry out the agricultural project.

October 3, 1967

Method of Transportation of Sludge

In our investigations we have studied three alternative methods of sludge transportation -- pipeline, rail and barge. The results of our studies thus far indicate that the pipeline will be the most economical, followed by rail transportation, with barge transportation probably being the most expensive. However, while there are fairly substantial differences in the presently estimated costs of the three alternative methods, we do not consider our studies to be sufficiently accurate at this time to definitely establish a superiority of one method over another.

The engineering and construction programs shown on Exhibit D indicate that a decision on a method of transportation of sludge to the Essex site can be deferred until late 1968, without delaying the initial operation of the Phase 3 project. A somewhat earlier decision may be necessary for the Phase 2 project, if excessive truck hauling and traffic is to be avoided in 1970 and 1971. However, we believe that Phase 2 can be accommodated for those years if a decision on the ultimate method of transportation is made by about May, 1968.

Therefore, we recommend that a definite decision on the method of transportation not be made at this time. This would allow additional time to study alternative methods of transportation and to obtain a more precise evaluation of each alternative. More importantly, it also would maintain flexibility in the general program.

Future Engineering Program

Exhibit D shows that certain steps of land acquisition and engineering design will be necessary prior to the initiation of construction of the facilities for the sludge utilization project. Design studies will need to be initiated at the earliest possible date for the Tinley Park site. Exploration and design studies for the Essex site would require more time for completion but should be initiated concurrently with the Tinley Park studies.

The recommended design studies will consist of two phases: (a) design report studies -- for the purpose of establishing functional design and preparation of design criteria, and (b) preparation of contract documents -- for purposes of site construction.

It should be noted particularly that a detailed study of an equitable division of increased net income between the District and the farmer will be an essential prerequisite to land acquisition, particularly where lease-back arrangements to the existing owner are contemplated.

Mr. Vinton W. Bacon

October 3, 1967

It has been a pleasure to be of service to you in this most interesting and important project. We will be pleased to discuss any questions you may have.

Very truly yours,

HARZA ENGINEERING COMPANY

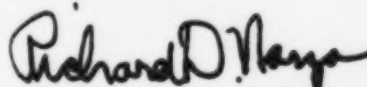

Richard D. Harza
Vice President

Table A

ECONOMIC COMPARISON OF ALTERNATIVE PHASEPHASE 3 SITES

<u>Item</u>	<u>Andres</u>	<u>Coal City</u>	<u>St. Anne</u>	<u>Essex</u>
Estimated Cost of Land Purchase per Acre	\$ 775	\$ 600	\$ 425	\$ 400
Construction Cost <u>1/</u>	45,000,000	56,000,000	52,000,000	47,000,000
Average Annual Cost <u>2/</u>	3,800,000	4,700,000	4,500,000	4,200,000
Average Cost per ton Sludge, Excluding Digestion <u>3/</u>	8.80	10.90	10.50	9.80
Total Cost per ton, with Digestion <u>4/</u>	21.30	23.40	23.00	22.30
Net Annual Income with Project <u>5/</u>	837,000	1,150,000	1,150,000	1,150,000
Increases in Net Annual Income	-48,000	339,000	546,000	581,000
Annual Increase in Indirect Benefits <u>6/</u>	-39,000	278,000	448,000	476,000

1/ Assumes use of pipeline and includes land, pipeline and pumping facilities, farm development, contingencies, engineering, overhead, and interest during construction.

2/ On basis of 6 percent interest rate and amortization of all construction costs over 50 years, and including maintenance and operation of sludge and irrigation water distribution.

3/ Without deduction of portion of agricultural income to be allocated to District

4/ Based on cost of \$12.50 per ton of undigested solids for Imhoff tank and heated digestion.

5/ To be divided between Sanitary District and farmers on basis of decisions yet to be made.

6/ Based on 82 percent of the annual increase in net agricultural benefits with the project, as used by U. S. Bureau of Reclamation.

TABLE B

COMPARISON OF ESSEX AND ANDRES SITES

Advantages of Essex Site

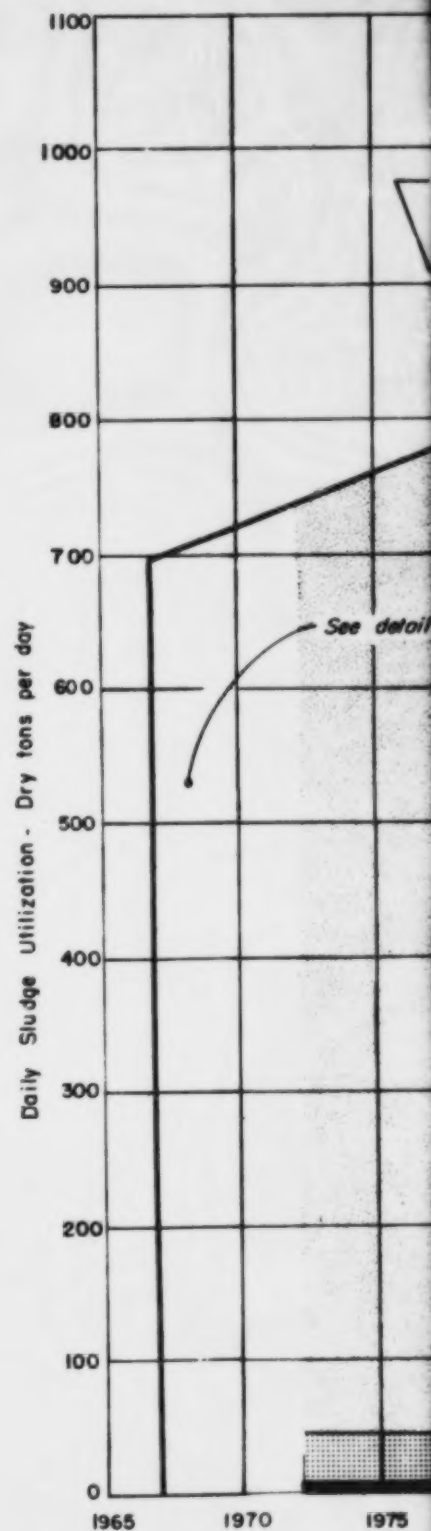
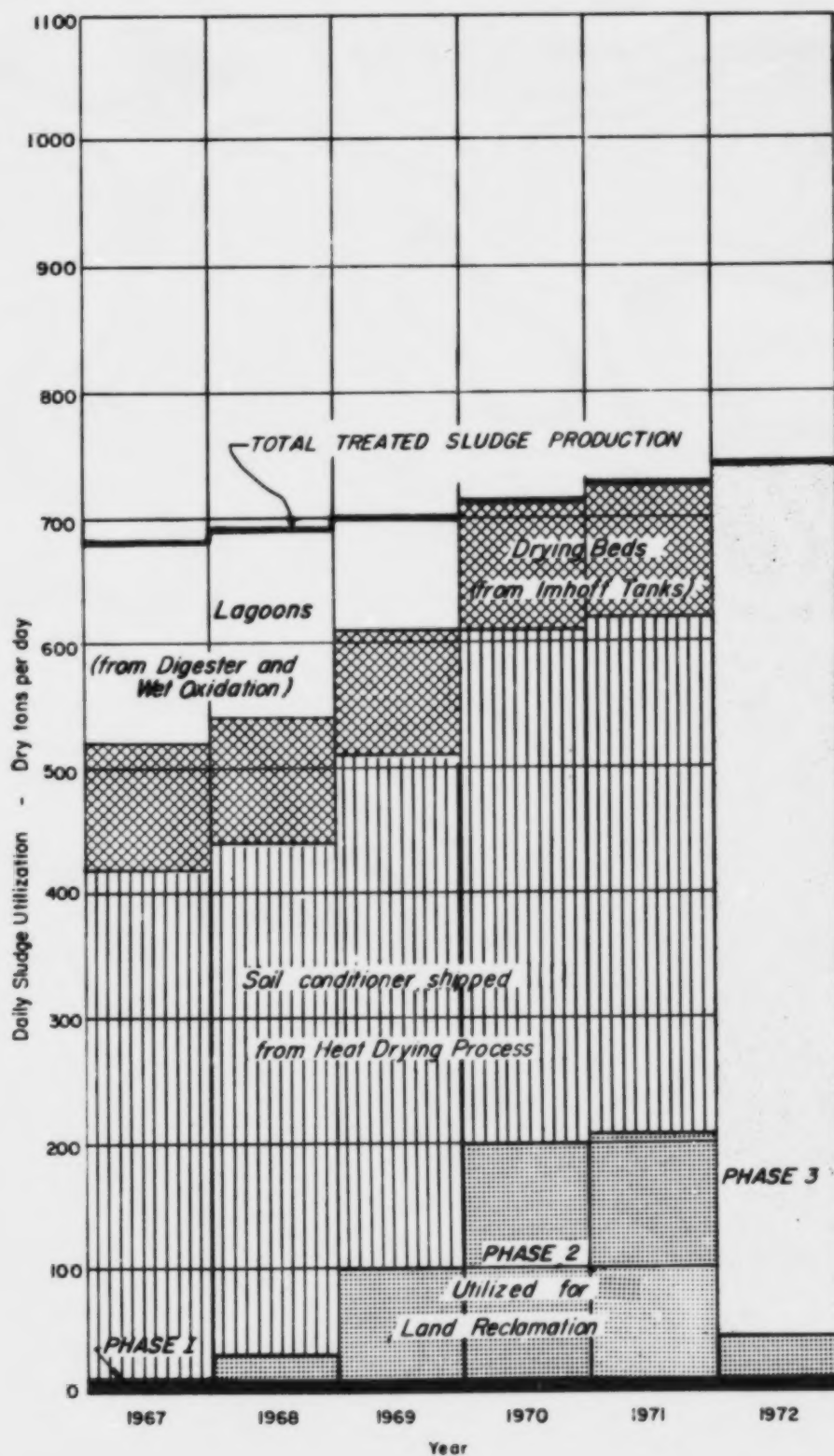
1. Project increases net agricultural income by \$581,000 (compared to reduction of income of \$48,000 by project at Andres) and, therefore, is a true upgrading and reclamation project.
2. Less dislocation problems -- fewer people in project area.
3. Easier to purchase because of (a) highest percentage of idle land, (b) least productive land and (c) smallest percentage of owner-operators on farm.
4. Better protection of surface water because less surface runoff from site area and higher dilution capacity in receiving streams.
5. Probability of longer life of project, since corrective measures in event of problems of soil - plants relationship can be more easily applied.
6. Greater flexibility for transportation of sludge, since barge, railroad, and pipeline all could be used.
7. Most favorable for crop production management.

Advantages of Andres Site

1. Slightly lower capital outlay by Sanitary District.
2. No problems of water supply availability.
3. Somewhat easier protection of groundwater, since there is more storage capacity in soil for nutrients.

4. Closer to Sanitary District, for management and for public viewing.
5. All in one county (does not involve difference between County regulations and attitudes).

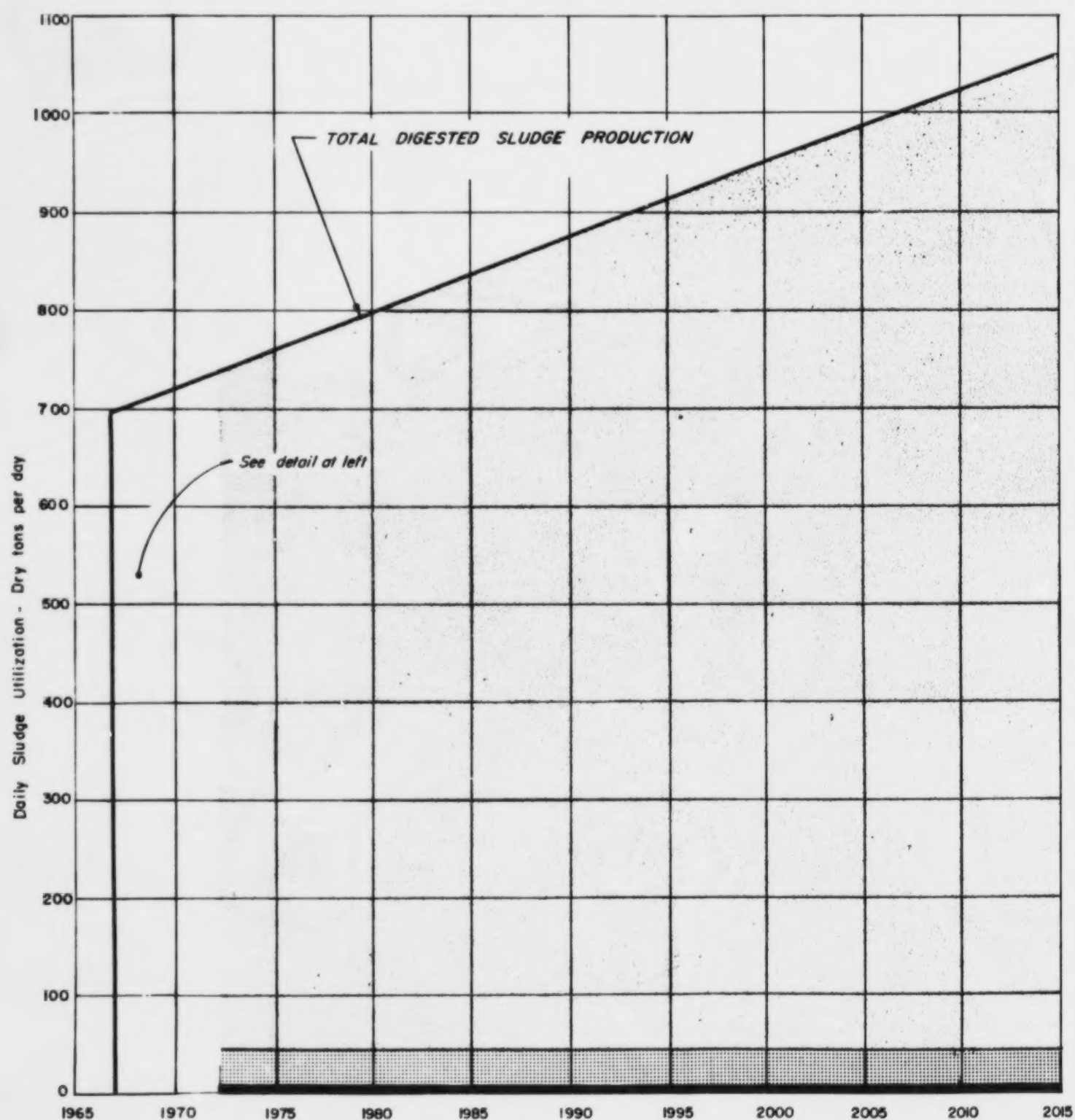
NOTE: There is no significant difference between the two sites in net annual cost to Sanitary District of sludge disposal.



LEGEND

	Phase 1 Land Reclamation Development
	Phase 2 " " "
	Phase 3 " " "

EXHIBIT A



LAND RECLAMATION PROJECT
SLUDGE
 UTILIZATION SCHEDULE

B

EXHIBIT B

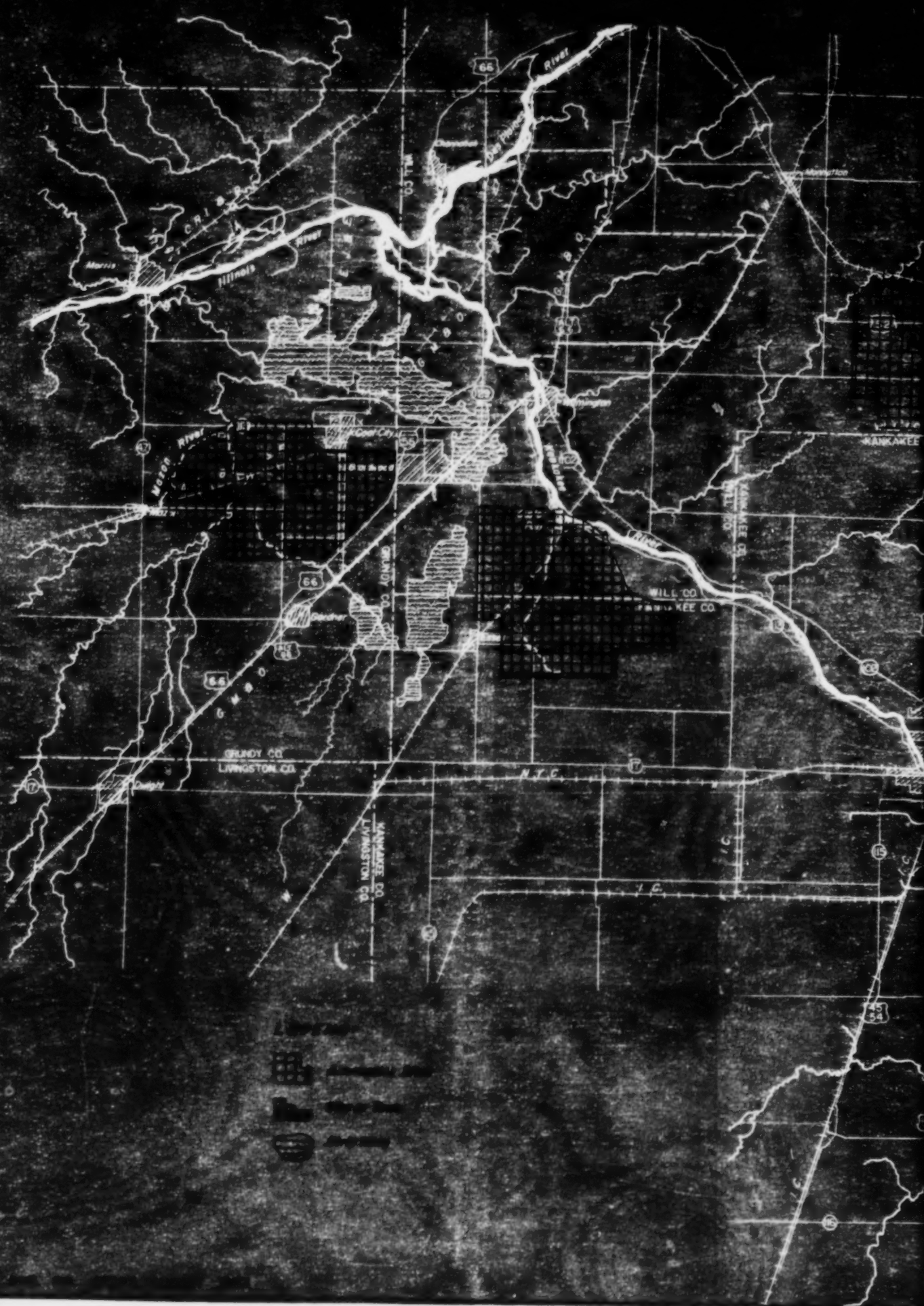
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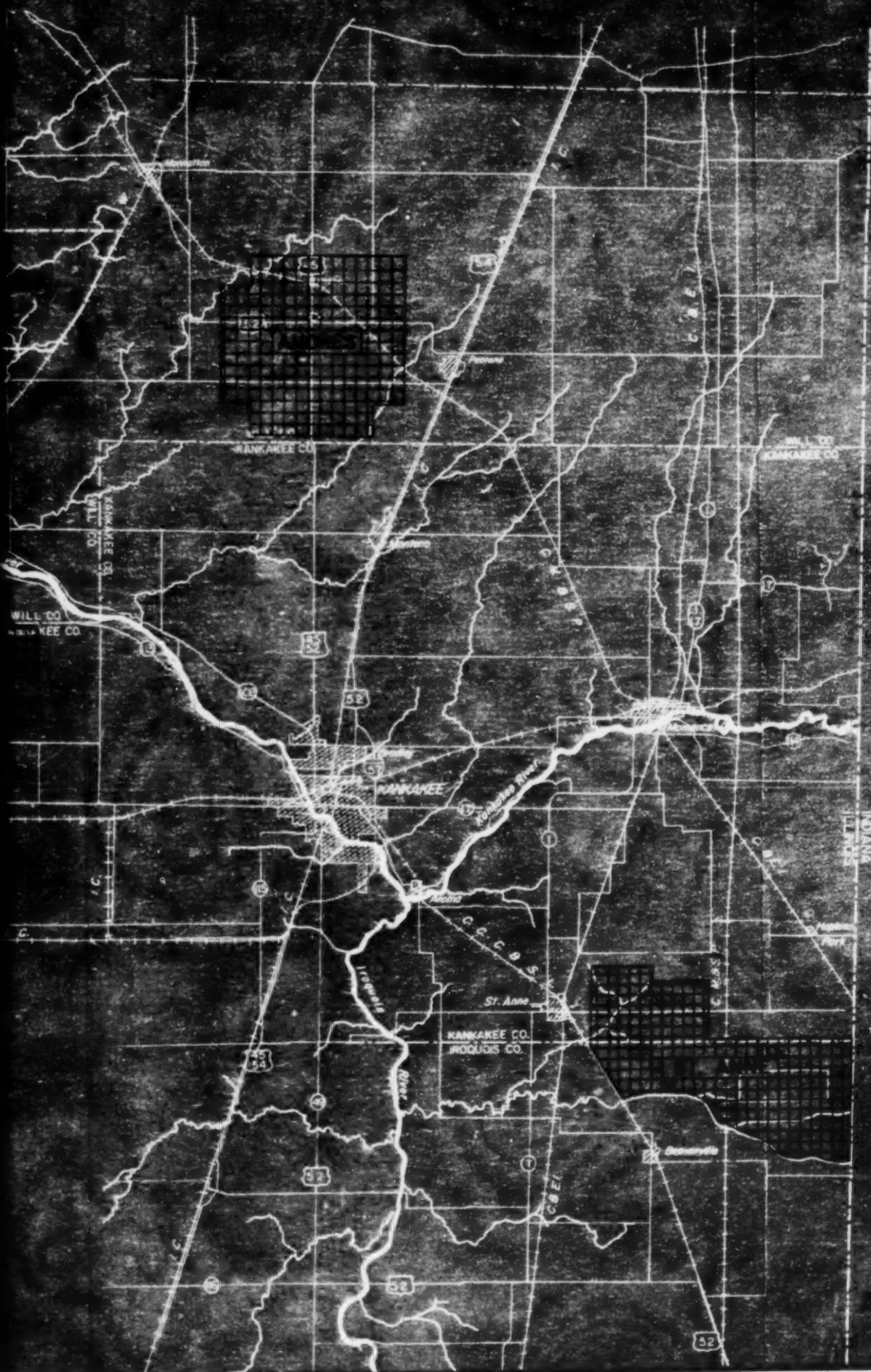
-  Alternative Phase 2 Sites
-  City of Chicago
-  Residential
-  Commercial
-  Industrial
-  Public Buildings
-  Airports
-  Higher Education
-  Public Open Space
-  Golf Courses
-  Cemeteries
-  Outdoor Amusement
-  Agriculture / Vacant
-  Mines



LAND RECLAMATION PROJECT ALTERNATIVE PHASE 2 SITES SOUTH COOK COUNTY

R





LEGEND

- Study soil area
- Gravelly sandstone
- Shale and sandstone
- Shale and sandstone
- Shale and sandstone

Scale 0 1 2 3 4 Miles

ALTERNATIVE PHASE 2 SITE

DESCRIPTION		1967	1968	1969	1970
PHASE 1	W-SW Plant Plot				
	Apply Sludge				
PHASE 2	-Cook County Site				
	Land Purchase				
	Design Studies				
	Grading and Construction				
	Apply Sludge 1st Block				
	2nd Block				
	3rd Block				
	4th Block				
PHASE 2 C	-Cooperative Sites				
PHASE 3	-Ultimate Project				
	Exploration and Design				
	Land Purchase				
	Site Preparation and Construction				
	Apply Sludge				

LEGEND

- Engineering, Land Acquisition & Construction
- High-rate sludge loading
- Standard-rate sludge loading

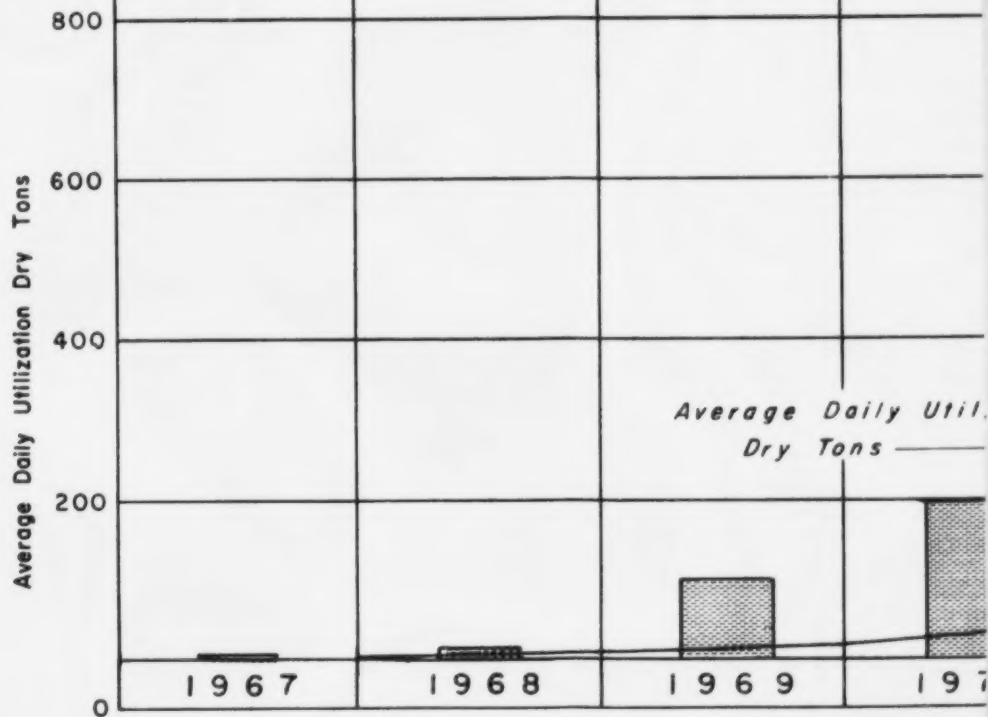
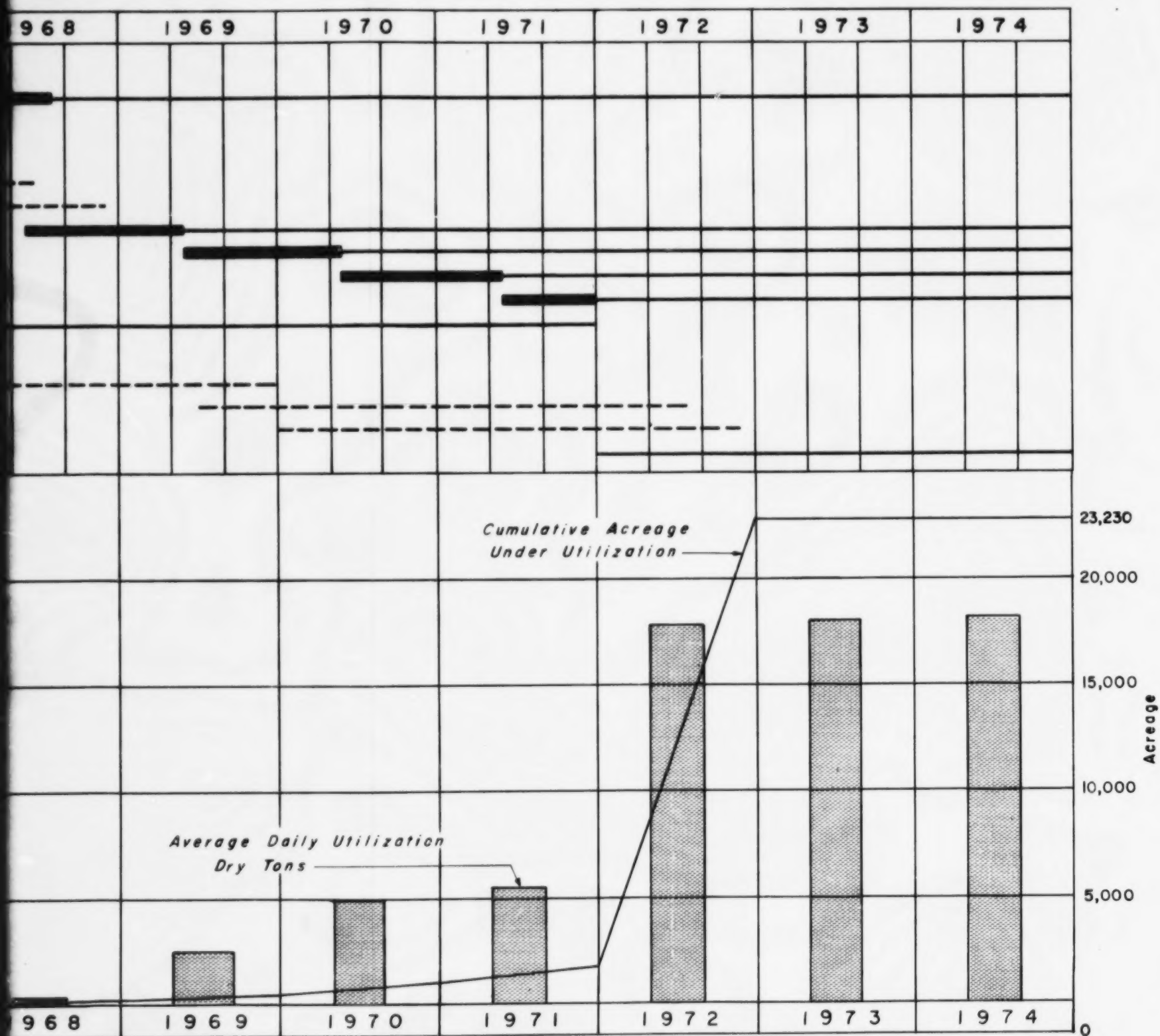


EXHIBIT D



LAND RECLAMATION PROJECT
DEVELOPMENT PROGRAM
FOR SLUDGE UTILIZATION SITES

B

SLUDGE DATA

For 20 Tons/Acre/Year/Average Application Rate:

Annual depth of liquid	5.0 in.
Annual depth of dry sludge cake	0.3 in.
Annual total Nitrogen application *	1,830 lb./Acre
Annual available Nitrogen * (Excl. mineralization of organic nitrogen)	690 lb/Acre

Total Sludge Production:

Total dry solids, year 2015	1,060 T/da.
Annual liquid volume	8,100 AF/yr.
Conveyance requirement (at 3.5% solids in 2015)	11.2 cfs
(for 95% load factor)	11.8 cfs

Irrigation Requirements:

Average annual irrigation require- ment	1.5 AF
Average annual application for 20,000 Ac	30,000 AF
Maximum diversion rate for 20,000 Ac	320 cfs

Ground Water

Average annual recharge rate (0.5 cfs/sq.mi.)	0.6 AF
Deep percolation (irrigation losses)	0.5

*Based on present analysis of 1,600 ppm Total N, 600 ppm NH₃ form.

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REPORT

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- II. Phase 1 and 2 — Sludge Utilization Program
- III. Route and Area Selection — Phase 3 Site
- IV. Agriculture Economics
- V. Preliminary Design of Phase 3 Project
- VI. Environmental Considerations
- VII. Recommended Engineering Studies and Investigations

Chapter I

INTRODUCTION

The Metropolitan Sanitary District of Greater Chicago has proposed a plan to utilize the inherent fertility of its sludge to upgrade the agricultural productivity of sandy soils. This plan would create a use for the sludge and obviate further need for operating costly facilities which have caused some problems in the past. This Land Reclamation concept has been studied by the Sanitary District, and they have concluded that it is feasible and economically justified. The investigations described in this report have been limited primarily to selection of the site best suited for a land-reclamation project and to determine the type and route of the conveyance system best suited to deliver sludge to the selected site. The investigations have been carried out under basic planning criteria furnished by the Sanitary District.

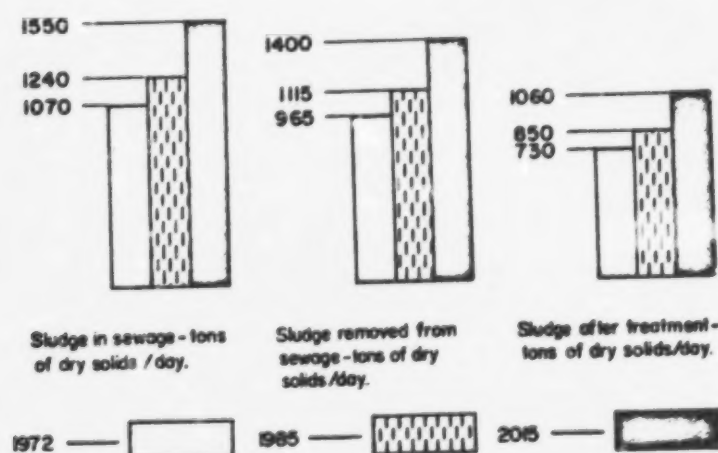
Sludge Production

The estimated average rate of accumulation of dry sludge solids at Sanitary District sewage treatment plants in 1966 was 900 tons per day. The District estimates that increased industrial contributions and home garbage grinders will increase the quantity of untreated solids from the present amount of 0.4 pounds per capita to 0.5 pounds.^{1/} This increase in solids, combined with the estimated increase in population, will result in an estimated accumulation rate of about 1510 tons of dry sludge solids daily in year 2015. Figure I-1 shows (a) the estimated average

^{1/} Reports on Sludge Disposal - Calumet Plant, Greeley and Hansen Consulting Engineers - Volume V, Part 2, May 1966.

amount of sludge produced each day, (b) the amount removed in the treatment process assuming 90 percent removal of suspended solids in sewage treatment plants, and (c) the amount remaining after digestion.

FIG. I-1



Figures developed from estimates of sewage solids by Greeley and Hansen, Consulting Engineers, Reports on Sludge Disposal, Calumet Plant, May 1966.

Treatment plant efficiencies calculated from annual reports of Maintenance and Operations Department of the Metropolitan Sanitary District.

Exhibit 1 shows estimates of sludge for disposal through the year 2015 based on the Greeley & Hansen report. The quantities are based on the assumption that future sludge treatment will consist of heated digesters and the existing Imhoff tanks for stabilization and reduction of solids.

Sludge is now processed at the West-Southwest and Calumet sewage treatment plants using four methods of treatment to reduce sludge volume. The process includes (a) unheated digestion, (b) heated digestion, (c) heat drying and (d) wet oxidation. Flow diagrams of the treatment processes are shown in Appendix A. The cost of sludge disposal by these processes is in the order of \$45 to \$50 per ton of dry solids.

All of these methods convert sludge to an inert form that is free from objectionable odors.

In a report dated April 1966^{1/}, Greeley and Hansen recommended to the Sanitary District the construction of additional heated digestion facilities and construction of incineration units. Proportioning the estimated costs of additional facilities to estimates of additional sludge volumes in 1975, the cost per ton of dried solids disposed would be about \$48. Thus, it appears that expansion of sludge treatment capacity using conventional sludge processing methods would continue to represent the same substantial operating cost to the Sanitary District.

The Greeley and Hansen report also considered, mainly for cost comparison purposes, the disposal using sludge lagoons at areas away from present disposal sites. The lagoon disposal scheme showed a significant cost advantage over other plans considered, both in total investment and in annual cost. However, investigation of a land reclamation approach to disposal was not a part of the Greeley and Hansen assignment.

In addition to the above methods, several experiments have been made in recent years demonstrating that digested sewage sludge can be employed successfully for land reclamation. The engineering staff of the Sanitary District recognized that land reclamation offered a potential solution to the sludge disposal problem and in February 1967, proposed a large scale land reclamation plan.

^{1/} "Reports on Sludge Disposal - WSW Plant," Greeley and Hansen Consulting Engineers, Volume V, Part 1, April 1966.

The Land Reclamation Project - A Solution

The Sanitary District proposes that sludge be applied to land in thin layers and incorporated into the soil as part of a total agricultural management and reclamation program. As a result of the studies by their engineering staff, the Sanitary District has concluded that the land reclamation concept is technically and economically feasible and that the concept should be implemented at the earliest possible date. Under this concept the sludge will be used productively in resource conservation and this use will provide for disposal at a fraction of the costs of any known alternative method.

The Sanitary District has contracted with the University of Illinois to conduct a three-year study of agricultural benefits and environmental changes resulting from the use of digested sludge on cropped fields. The study by the University of Illinois will be completed by February 1970, with completion of intermediate studies by March 1968 and March 1969. The Sanitary District also retained the Harza Engineering Company to select the site or sites that would be the most suitable for sludge utilization and to evaluate the routes and means for conveyance of sludge to the selected site or sites.

Investigation Objectives

The specific objectives of this report are as follows:

- (a) To select the most suitable sites for reclamation, of a size necessary to utilize the sludge production in the year 2015.
- (b) To select the route alignment for the conveyance system, with a review of alternative conveyance methods.

- (c) To develop a staged plan of development, including possible use of areas separated from the principal land reclamation site.
- (d) To develop a general plan, with capital costs, costs of operation, and preliminary estimates of economic benefits.
- (e) To outline the needs and costs for the next stage of engineering, leading to preparation of the final design, plans and specifications.

Acknowledgments

We wish to acknowledge the advice and assistance of the Sanitary District staff. In addition, we wish to acknowledge the cooperation given by officials of the State Water and Geological and Natural History Surveys, State Department of Conservation, Cook County Forest Preserve, Peabody Coal Co., Springfield Sanitary District and State Department of Public Health.

The studies were supported, in part, by a demonstration and study grant from the Office of Solid Waste Disposal, U.S. Public Health Service.

Harza Engineering Company has been assisted, for the conveyance system studies, by Bauer Engineering, Incorporated. The following were the principal participants of the two firms in preparation of this report:

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Chapter II

PHASE 1 AND 2 - SLUDGE UTILIZATION PROGRAM

Overall Development Schedule

A staged schedule is recommended for the development of an agriculturally oriented sludge utilization program. The schedule is shown on Exhibits 1 and 2. Staging will allow early diversion of digested sludge production from lagooning to beneficial use. It also will permit orderly development of agricultural-management techniques in parallel with the development of research information from the University of Illinois investigations. The recommended schedule begins with utilization of a small amount of sludge in 1967, increasing by stages to full utilization in 1972.

Phase 1 of the staged program is a small scale field test on a few acres of grass land at the West-Southwest (WSW) Sewage Treatment Plant. Preparations for this test are underway at present (October 1967). This field test is being conducted to confirm the utility of standard agricultural field piping and sprinkler systems for sludge application before embarking on large-scale programs. It also will develop insight on limits to the rate of application of sludge to soil under grass cover.

Phase 2 of the staged program is recommended to be an accelerated, full-scale field application of digested sludge on an agricultural site of 1720 acres in Southwest -Cook County. The objective of Phase 2 is to provide an area in Cook County on which full-scale utilization can be initiated at a very early date. The Phase 2 project is designed to accept the full production of sludge, in excess of present disposal capacity. Phase 2 will come into operation in 1968 and

reach its peak in 1971, when the sludge utilization rate is estimated to be 230 tons per day (dry solids). The Phase 2 project also will serve as a model area where the use of sludge can be publicly exhibited to illustrate the characteristics and benefits of the concept.

Phase 2C of the program will consist of cooperative arrangements with various public and private organizations, in which sludge would be applied and utilized on lands in present ownership. Although not essential from a viewpoint of sludge disposal, it would be highly beneficial in passing benefits to public agencies, in demonstrating these benefits, and in adding flexibility and reserve capability to the overall program.

Phase 3 of the stage program is recommended to be the development and operation of a site of 21, 500 acres on agricultural lands in a sandy soil area near Essex, in Will and Kankakee Counties, where the sludge application would be particularly beneficial. This stage is scheduled to begin operation in 1972 and can accept the full production of digested sludge from the Sanitary District's three major plants.

Phases 1, 2, and 2C of the recommended implementation program are described in greater detail in the remainder of this chapter. The details of Phase 3 are described in Chapter III.

Phase 1 - Equipment Demonstration

Phase 1 is a small-scale field test of conventional field piping and sprinkler systems which are proposed for use in applying sludge to agricultural land. The test will allow for observation of the performance of the distribution equipment with digested sludge and modification, if necessary, before acquisition and placement of equipment for the 1720 acre Phase 2 project.

Phase 1 operation also will serve for development of practical experience and for training of Sanitary District personnel who will maintain and operate the distribution facilities at the Phase 2 site. Tests will be made to determine the upper limits of sludge application rates for grass covered soils. Evaluations also will be made of the effects of sludge sprinkling on the environment under various climatic conditions.

The recommended site for the Phase 1 project is on the grounds of the WSW Sewage Treatment Plant. A layout sketch of the recommended location and distribution system is shown on Exhibit 3. The site is to the west of the main entrance road between the laboratory and the Battery C aeration tanks and could comprise up to about 10 acres. Three test plots will be served by single sprinklers. The sprinklers will receive digested sludge through a six-inch pipe line from the sludge digestion complex. It is proposed that this test system be installed by Sanitary District personnel using conventional equipment. Preparation of the Phase 1 project is presently underway (October 1967).

Observations should be made of soil and soil moisture characteristics prior to, and at intervals during the operation of the system. Auger borings to ground water should be made in each test plot prior to, and at intervals during the operation, to determine the elevation of the water table and the quality of the ground water. The reaction of the existing grass cover to the different application rates should be observed and recorded.

Since it is anticipated that first-year applications of sludge to the Phase 2 site will be to soil under grass cover, the suitability of different varieties of grasses should be tested on the Phase 1 site as early as possible in 1968. For this purpose, each of the three test plots should be cultivated and seeded with three to four rough grass varieties

in sectors. These varieties should include Rye, Brome, and Reed's Canary grasses.

Observations of the effect of climatic conditions on system operation should be recorded. These should include the effect of wind speed on sprinkler drift, the effect of varying sludge application rates on rain infiltration and runoff, and the effect of low temperatures on equipment operation. Sprinkler equipment should be inspected at intervals to determine the effects of the sludge.

Phase 2 - Accelerated Application on Cook County Site

General Plan

Phase 2 is to be a full-scale agricultural management operation, using an accelerated rate of application of digested sludge for land and crop production improvement. A site of 1720 acres near Tinley Park, in south Cook County, has been selected for the Phase 2 site which should begin operation in the summer of 1968. During 1970 and 1971, it is designed to accept the full production of digested sludge and wet oxidation ash presently being deposited in lagoons in accordance with the schedules shown on Exhibits 1 and 2. It is assumed that the present sludge drying beds, heat drying, and wet air oxidation operations will continue through 1971. The Phase 2 project will be required to accept an average of 230 tons per day (dry solids) in 1971, its last year of accelerated application.

Operation of the Phase 2 project will allow reduction of digested sludge lagooning in early 1968 and termination in early 1970. Some lagoon space will be required, however, during Phase 2 and Phase 3 for operational storage purposes.

The possibility exists that all or part of the land presently used for sludge storage lagoons could be reclaimed with the sludge in place. This would allow early sale of these lands by the Sanitary District and eliminate the need for conveyance of the lagooned sludge to the Phase 3 project site. It is recommended that studies be carried out in the next phase of engineering to explore this possibility.

In addition to its primary function of utilizing sludge, the Phase 2 site will allow demonstration of sludge utilization techniques to agencies and individuals who will be concerned with the development of the Phase 2C and Phase 3 sites and with other sludge utilization possibilities. The Phase 2 operation also will allow for refinement of agricultural management techniques for the Phase 3 project, as well as for the land disposal project contemplated for the planned northwest Cook County sewage treatment plants.

Since the Phase 2 site is to be designed for accelerated loading in the initial years of operation, it will not be possible after 1971 to continue use of all of the production presently deposited in lagoons, without additional sites for sludge utilization. For this reason, either Phase 2C or Phase 3, or both, must be ready for operation in 1972.

Potential Phase 2 Sites

The schedule of operations for the Phase 2 site calls for limited operation in 1968, with substantial utilization of sludge in 1970 and 1971. This means that a site, located relatively nearby, must be available in the next few months. To assure this availability, the site must be located within Cook County, where land acquisition will be less difficult. Of the relatively small amount of remaining open land in the County there are no sandy soil sites which are suitable for this scale of development.

A reconnaissance for suitable sites was made in the southern portion of Cook County because of the proximity of the two digested sludge sources--the Calumet and WSW Sewage Treatment Plants. The principal consideration in the site reconnaissance was proximity to present or near-future urban developments.

Sites having sufficient acreage to accept sludge for the desired period are shown on Exhibit 4. All of these sites have medium to heavy soils of glacial, lake, or glacio-fluvial origin, with gentle to severe slopes. The dominant soil types are Frankfort silt loam and Milford silty-clay loam, having moderate to moderately poor infiltration rates. Soil fertility levels vary from farm to farm on these soils, but most of the soils have been depleted of much of the carbon and nitrogen inherent in prairie soils.

Maximum Loading Rates

It is proposed that sludge be applied at relatively high rates for a high initial improvement of soil fertility. This manner of sludge loading differs from the lower rates recommended for the Phase 3 site for several reasons:

- (a) The production of digested sludge is high with respect to the amount of land available.
- (b) The Phase 2 site will have to accept sludge at the high rate for only a limited time, 1968-1971.
- (c) In contrast to the sandy soils in the Phase 3 site, the heavy soils in Cook County drain more slowly, making agricultural operations difficult to carry out if sludge is applied continuously at the rate of 20 tons per acre per year established by the District as criteria for the

Phase 3 site. Therefore, it is proposed that a heavy application be made on grass cover the first year, with only light application to that same plot in the following year when it would be cultivated and cropped.

Selection of the acreage requirement for the Phase 2 site is based on the schedule of sludge production in 1968-1971 and the maximum rate at which sludge should be applied. Little is known at present of the maximum rates at which liquid sludge can be applied to medium soils under climatic conditions of Northern Illinois. The rates of application will be governed by:

- (a) The climatic and soils conditions which determine the removal of water from the sludge.
- (b) The depth of sludge that can be tolerated on the plant leaves.
- (c) The maximum desirable nutrient level in the soils.
- (d) The physical restrictions which the application of sludge may place on farming operations.

The climatic and soil infiltration limit (based on evapotranspiration of 29 inches, growing season rainfall of 20 inches, and probable recharge to groundwater of 11 inches) would be 20 inches of water, equivalent to 80 tons per acre per year of dry solids. However, actual experience in Pennsylvania, where 50 to 60 inches of sewage effluent was applied annually under less favorable climatic conditions, indicates that the estimated limit of 80 tons per acre per year is probably low.

Soil storage capacity for nitrogen probably establishes the nutrient limit for the soil. The soil reservoir (to 30 inches depth) now probably contains 10,000 to 15,000 pounds of organic nitrogen per acre. It could probably hold 15,000 to 20,000 pounds additional per acre. This

would suggest a loading limit of 270 to 360 tons per acre. This level of nitrogen storage in the soil reservoir would provide an annual release of nitrate in excess of vegetative needs and might result in leaching of nitrate to the ground water at concentrations up to 2500 parts per million of available nitrogen. This does not take into account the substantial dilution effect of the ground-water body.

Farming operations could not continue on a normal pattern during the one-time heavy loading. It is proposed that the heavy loading be applied to the soil under a grass cover and normal farming operations be carried out the following year. It is believed that a suitable grass, such as Brome or Reed's Canary, would assimilate moisture more rapidly than barren soil and would not be subject to erosion loss.

From the above considerations, it is apparent that precise establishment of a maximum loading rate for the Phase 2 site is not possible. However, experience and rational analysis suggest that a one-time loading slightly over 100 tons per acre per year is reasonable. It is recommended that an average first year loading rate of about 125 tons per acre annually be used for planning and land procurement for the Phase 2 site.

It also is recommended that actual application during the first year be in the form of an array of ten annual loading rates ranging from 300 tons per acre to 10 tons per acre, plus a control plot. The proposed schedule, shown in Table II-1, is designed to give an average of about 115 tons per acre in the first year of operation. In subsequent years, the high and low extremes probably would be discontinued for new areas, and some moderate applications would be made to previously-treated areas giving an average loading of about 125 tons per acre per year. The resulting land development schedule is shown in Table II-2.

Table II-1

PHASE 2 SITEINITIAL YEAR APPLICATION SCHEDULE

<u>Plot No.</u>	<u>Loading (tons per acre)</u>	<u>Objective</u>
1	300	One-time loading
2	250	One-time loading
3	200	One-time loading
4	150	One-time loading
5	150	One-time loading
5	100	One-time loading
6	75	One-time loading
7	50	One-time loading
8	25	One-time loading
9	10	One-time loading
10	0	Control plot
$\frac{1,160 \times 10A}{100A} = 116 \text{ Tons per acre average}$		
$\frac{1,160 \times 10A}{365} = 32 \text{ T/day utilized}$		

Table II-2

LAND DEVELOPMENT SCHEDULE

<u>Year</u>	<u>Average Loading (tons per acre)</u>	<u>Sludge Utilized</u>		<u>Area Developed (acres)</u>
		<u>(tons per year)</u>	<u>(tons per day)</u>	
1968	116	11,600	32	100
1969	130	39,000	107	300
1970	130	73,000	200	560
1971	130	89,500	245	690
Total developed				1,650
Plus borders, roads (4%)				70
TOTAL LAND REQUIRED				1,720

At present little is known of the maximum rate of sludge application that can be made after the initial accelerated application. There is some possibility that little or no application can be made concurrent with farming operations. For purposes of these studies, it has been assumed that the application rate at the Phase 2 site after 1971 will be half of that specified for the Phase 3 site, or 10 tons per acre per year. As can be seen on Exhibit 1, this assumption has little effect on the land requirements for the Phase 2 site.

Site Selection

The land development schedule shown on Table II-2 indicates a land requirement of about 1720 acres for the Phase 2 site. Of the sites shown on Exhibit 4, there are no apparent advantages of one site over the others in cost or in types of soil. The 1720-acre site south of Tinley Park (Exhibit 5) is recommended for the Phase 2 site, for the following reasons:

- (a) The topography is most favorable--the land slopes are generally flatter, with the exception of one minor escarpment.
- (b) The area is bordered by the Forest Preserve on the east, which favors the maintenance of adjoining land in open space.

Operating Considerations

It is recommended that land purchases be made under arrangements whereby the present owner could, if desired, lease back the land for agricultural purposes, under operational controls maintained by the Sanitary District.

Operations will be conducted on the Phase 2 site in a program of increasing scale, beginning with 100 acres early in 1968. Sludge should be conveyed to the site by trucks during the initial year or two, because this method will allow the Sanitary District much greater flexibility for planning Phase 3 site and conveyance facilities. It is probable that the loading rates scheduled for 1970 and 1971 will require an excessive amount of trucking, so that permanent conveyance facilities should be arranged by that time.

Field application should be made on grassed areas. No attempt should be made to grow field crops during the same year in which a given plot is to receive sludge. Otherwise, to achieve maximum operating experience, operations should be conducted as nearly as possible in the manner anticipated for the much larger Phase 3 site, as follows:

- (a) Sludge should be applied by sprinkler-irrigation equipment.
- (b) To the extent possible, 3.5 percent solids should be utilized.
- (c) Agricultural crops should be produced.
- (d) Environmental hazards should be prevented.

Sprinkler equipment is proposed because of its inherent advantages for heavy application rates and its usability on sloping land. In addition, operation of sprinklers on the Phase 2 site will permit the Sanitary District personnel to gain experience with the equipment and to make any required modifications prior to starting on the ultimate site.

The digesters now produce sludge of three percent solids or less. In Phase 2 it will be desirable to apply sludge with much higher concentrations to accomplish the desired loading objectives and avoid undue

trucking quantities. These higher concentrations can be achieved by using sludge from the lagoons, where the sludge concentration is as high as 30 percent. Therefore, it is recommended that, at least during the trucking operations of Phase 2, sludge be taken from the lagoons for transport to the Phase 2 site, with the production from the treatment plant being deposited in the lagoons during that period.

The detailed cropping schedule for the Phase 2 site requires further study, but at this time it appears that corn and soybeans should be the main crops. They will respond well to the high fertility of the treated soil and will provide a high rate of income from the land.

Several land development steps will be taken to implement the utilization of sludge including:

- (a) Extension and improvement of drainage system.
- (b) Grading and terracing of field plots.
- (c) Construction of storage facilities to retain drainage.
- (d) Installation of the sludge-distribution system.

Steps taken to prevent environmental hazards will include (a) confinement of surface runoff at times when it could contain sludge and (b) reducing or modifying applications when monitoring observations indicate the possibility of hazards. These monitoring facilities and procedures will be specified during the design studies, and they will include observation wells, stream and air sampling, and analysis of plant-tissue samples.

Phase 2C - Cooperative Sites

Phase 2C is a plan to utilize sludge for fertilizing or up-grading of lands not in the ownership of the Sanitary District. The plan would be mutually beneficial in that the cooperating organization could receive the land treatment which it requires at little or no cost, while concurrently the Sanitary District could reduce its land requirements for sludge utilization. This phase also would have the advantage of demonstrating the benefits and safety of sludge utilization to a wider portion of the public. Phase 2C should be initiated at the same time as Phase 2, if possible, and extend beyond 1971.

Potential Cooperative Sites

A preliminary investigation has revealed seven potential cooperative sites where sludge might be utilized, mainly to establish or upgrade desirable cover planting such as turf. The land areas range in size from 1000 to 4000 acres, at locations 10 to 50 miles from the WSW plant. Characteristics of potential sites are summarized in Table II-3.

Table II-3

POTENTIAL COOPERATIVE SITES

<u>Site</u>	<u>Owner</u>	Distance ^{1/} <u>(miles)</u>	<u>Area</u> <u>(acres)</u>	<u>Remarks</u>
Wildlife Area	State	35	1,100	-
Joliet Arsenal	U. S. Army	35	4,000	Three areas
Highway ROW	County/State	10 (average)	---	Probably over 1000 acres annually
Forest Preserve	County	20 (average)	---	About 600 acres annually
Strip Mines	Various	80	1,000 ±	Excludes 14,000 acres near Braidwood
Turf Nurseries	Various	Varies	Varies	-
Private Farms	Various	Varies	Varies	-

^{1/} From WSW Plant.

Preliminary discussions have been held with some of the owners of the sites mentioned above. The reception has varied from reluctance to cautious interest. It is believed that some cooperation can be developed, provided the benefits to the cooperator are demonstrated and it can be shown that his primary purpose is not jeopardized.

Implementation

The Phase 2C sites would remain in present ownership; therefore, it will be necessary for the Sanitary District to convince those owners of the benefits they would realize from utilizing sludge. This objective could be obtained by organizing advisory committees from these potential cooperators to assist the Sanitary District in implementing this phase of the program. This approach would have the advantage of concentrating the demonstration efforts of the Sanitary District, rather than relying on separate contracts with each potential cooperator.

Implementation will require careful planning to assure that the effort would be a success. The potential sites comprise a wide variety of operating settings, with different slopes, soils, vegetative requirements and needs for environmental protection. Application facilities and operations must be designed to (a) produce beneficial improvements in the form of the desired vegetation and (b) to do so without hazard or nuisance. These requirements can be accomplished during the design phase studies, after the advisory committee has become active and the Sanitary District has selected cooperative sites and established development priorities.

Chapter III

ROUTE AND AREA SELECTION - PHASE 3 SITE

This chapter gives the results of studies leading to the selection of a land area for Phase 3 and the recommendation of an alignment and system for the conveyance of sludge to that land area. Land areas and conveyance systems were studied individually and in combinations to select the plan which best suited the purposes of the project. The details of the development proposed for the selected site are given in Chapter V.

Summary of Findings

It is recommended that the Essex site, Exhibit 6, be selected for land acquisition for the Phase 3 site. By far the most important consideration leading to this recommendation is the upgrading of crop production capabilities of the Essex site and, therefore, the greater benefit to existing agriculture and the greater positive economic impact it will have on the area. In contrast to this, it is anticipated that there would be less effect for the Coal City or St. Anne Sites and little or no economic benefits for Andres site. Because of this, a better acceptance by the local interests could be expected at Essex.

The results of our studies indicate that a pipeline would be the most economical conveyance system, followed by rail, and barge, with truck transportation being the most expensive. The studies have revealed that the most economical route for a pipeline location in the event that this method of transportation is ultimately selected, is as shown on Exhibit 7. However, while there are fairly substantial differences

in the presently estimated costs of the four alternative methods, the studies are not considered to be sufficiently accurate at this time to establish definitely a superiority of one method over another, when all aspects of the problem are considered.

The engineering and construction programs discussed in Chapter II indicate that the decision on a method of transportation of sludge can be deferred until late 1968, without delaying the initial operation of the project. A somewhat earlier decision will be required for operation of the Phase 2 site during 1970 and 1971, as discussed in Chapter II but a decision could be deferred to as late as May, 1968, without endangering implementation of the 1970 or 1971 schedule. Therefore, it is recommended that a definite decision on the method of transportation not be made at this time. This would allow additional time to study alternative methods and details of transportation and to obtain a more precise evaluation of each alternative. More importantly, it also would maintain flexibility in the general program.

The remainder of this chapter describes the details of the studies leading to the above recommendations. Following a section on the criteria for selection of the land sites, the chapter is divided into two parts. Part One describes the preliminary evaluations and comparisons that were necessary to narrow the possible alternatives to a few which could be studied in more detail. Part Two describes the detailed studies of four sites that were selected in the "screening" process described in Part One.

Criteria for Harza Studies

The following criteria were established for purposes of selection of the Phase 3 site:

- (a) The site to be selected should be one which would offer maximum benefits to the existing agriculture and would have the greatest benefit to the local economy, consistent with maintaining reasonable costs to the District.

- (b) The land must be susceptible to purchase by the Sanitary District, to assure that the sludge application is carried out under uniformly controlled conditions.
- (c) The selected site must be one in which it will be possible to protect ground water quality to areas outside the project boundary, protect water supply to the area within the project boundary, protect public health, be free of nuisances and odors, and be satisfactory esthetically.
- (d) The project area to be acquired should be approximately 21,500 acres, based on a sludge loading rate of 20 tons of dry solids per acre per year. All lands in the site should be contiguous, at least to a reasonable extent. Developed urban, recreational or industrial areas should be separated from the project lands by at least one half mile. Land ownership in the area should be in as large tracts as possible, thus offering the greatest potential for leasing the land back to the present owners and minimizing the disturbance to existing residents.
- (e) Thin soil cover over permeable bedrock is not considered suitable, because of the difficulty of conducting farming operations and of providing protection from pollution of ground water.
- (f) Land slopes should not be prohibitively steep to allow application of the sludge and to simplify

measures for protecting against excessive surface run-off.

- (g) A source of irrigation water supply should be available in areas in which soil characteristics are such that an upgrading of agricultural production cannot be accomplished without irrigation.

PART ONE - PRELIMINARY SCREENING OF ALTERNATIVES

Previous studies by the Sanitary District have focused on sandy-soil areas which are nearest to Chicago. The Harza investigations included, as a first step, a review of the District's findings. This was followed by a reconnaissance of all potential areas within reasonable distance of Chicago, including sandy-soil areas, areas of finer-textured soils, strip mines, etc. The screening process then was concentrated on sandy soils area, with three such areas selected for more intensive analysis. For comparative purposes, a fine-textured soil area also was selected during the preliminary screening for more detailed analysis.

Summary of Sanitary District Studies

The Sanitary District proposed that sludge be utilized to upgrade the productivity of agricultural lands and to upgrade the vegetative cover of mine-spoil areas. The studies examined three potential sites at (a) Hopkins Park, (b) Coal City, and (c) Essex. The conclusion was that the latter two sites were about equal in cost and that the Hopkins Park site was more expensive and less desirable from the standpoint of socio-economic considerations. The studies considered that sludge would be conveyed by pipeline from the Calumet and West-Southwest Plants, with the pipeline located mainly along the Illinois and Michigan Canal

right-of-way. The proposed development included agricultural land, as well as an adjacent mine-spoil area which was to have been developed for recreation use.

Reconnaissance of Phase 3 Sites

General

Soils maps and land productivity were examined for the entire area within 75 miles from the West-Southwest Plant. This would include all the sandy-soil sites investigated by the District. There are no large sites within this range which are relatively low in productivity except for sandy-soil areas and the coal-spoil areas. Some small areas have been found where soils have been eroded, exposing the sterile till subsoil. These locations could be upgraded by sludge applications, and two have been recommended to the Sanitary District for purchase to accommodate sludge production from the small plants proposed for the northwestern portion of the Sanitary District.

Sludge applications can be made satisfactorily on any soils, though the degree of upgrading of production is almost certain to be greater on the lesser productive lands. There were no sites found in Cook County which would be large enough for a Phase 3 site. However, a smaller site in Cook County, south of Tinley Park, has been recommended as a Phase 2 site, as previously described. For these reasons the reconnaissance was extended beyond Cook County.

Most of the area lying north and west of the Des Plaines River has undergone or is subject to intensive urban development. The extent of this development would tend to make site and right-of-way acquisition more complicated and costly. There are also fewer conveyance alternatives open to the west and northwest, since (a) there are no waterways,

(b) the railroads which serve this area do not pass near the main treatment plants, and (c) a pipeline route would have to cross extended distances of highly developed urban area.

Two fine-textured soils sites outside Cook County were screened, even though they have high productivity. They were studied to compare them with sandy-soil sites to provide an alternative site in the event that the sandy soils proved unsuited or unavailable.

Evaluation of Mine-Spoil Areas

About 14,000 acres of spoil area are located adjacent to the sandy soils, as shown by Exhibit 8. All but about 2000 acres is owned by private clubs for various recreational uses. The spoil ranges from very old mined-out areas, which are characterized by low-irregular ridges that are fairly well covered by vegetation, to newer areas which have high-parallel ridges that are often barren and rock strewn.

Feasibility. It has been established that sludge could be utilized beneficially on the spoil areas which do not yet have adequate vegetation. The mineral nutrients and organics contained in the sludge could, with other soil amendments, accelerate plant growth, reduce erosion, and obtain a cover on the spoil faster than natural restoration. Planting of selected vegetation could increase the wildlife values of these and other partially covered areas.

The nutrients might leach into the lakes which comprise the main recreational attraction of these areas. However, it is not now possible to say whether or not these nutrient concentrations would be great enough to impair aquatic life, or whether the addition of sludge might instead reduce the mineralization or leaching rates of harmful material contained in the spoil and now seeping into these lakes.

Evaluation of Mine-Spoil Areas. The conservation aspect of spoil reclamation is appealing; however, it appears that there is not an adequate area of spoil available for long term operations and that costs to the Sanitary District might exceed those for the recommended scheme. Also, some of the conservation interests at present do not consider the reclamation aspects to be sufficiently proven and are currently opposed to use of coal-spoil areas for this purpose.

Very little of the spoil in the Coal City-Essex area is likely to become available for sludge utilization in any reasonable time. About 2000 acres are owned by the mining company and might be available more readily than that in private clubs. At the annual 130 ton per acre loading proposed for the Phase 2 Site, this 2000 acres would not be adequate for even one year of the entire sludge production of the District after 1972. The loading of 130 tons per acre would provide adequate mineral nutrients and organic material to establish and sustain cover vegetation. Spoil reclamation would enhance the appearance and value of these areas, but it would not generate the crop returns which serve to upgrade the agricultural economy as in the sandy-soil areas. The main benefit would lie in the reclamation of the spoil as public recreation areas which would be capable of more intensive use and greater wildlife production.

Despite the lack of suitability of coal-spoil areas for a Phase 3 Site, it is suggested that the Sanitary District inquire further into the possibilities of including some spoil area in the cooperative Phase 2C program described in Chapter II. This would be a useful demonstration area and could provide results of value to the spoil-reclamation needs elsewhere. Federal grant programs are not known to cover this area, but the degree of interest shown by the Department of the Interior

indicates that inquiry may be justified. Their recent study^{1/} reports that two million acres of surface-mining spoil need to be reclaimed in the U.S. and that over 143,000 acres have been disturbed in Illinois.

Although some conservation interests are presently opposed to use of coal-spoil areas for sludge application, this opposition seems to stem from a genuine feeling that the areas will not be benefited. Demonstration of the benefits that can accrue through sludge application, as well as proof that water quality and other environmental factors will not deteriorate, could well change the position of the conservation interests. For this reason, a cooperative project under the Phase 2C program would be beneficial to demonstrate the enhancement of both wildlife production and appearance in the coal-spoil areas.

Screening of Sandy-Soil Areas

The extent of sandy soils was delineated and re-examined to assure that all potential sites had been considered. The present land use on such sites is shown on Exhibit 8. The screening evaluation included consideration of the several criteria by which possible sites could be delineated and compared, as described previously. These studies have established that sandy soils are best suited for the long-term utilization of sludge for agricultural production, and would provide the greatest agricultural benefits. The studies are described in Appendix C.

Numerous small tracts and housing developments are scattered over a wide area in the vicinity of Hopkins Park. The socio-economic problems related to the necessary relocation of many of the present residents were considered to be too great to consider seriously the Hopkins Park areas as a Phase 3 site.

^{1/} "Surface mining and our Environment," U.S. Department of Interior, 1967.

The criterion excluding areas with thin soil cover and permeable bedrock precluded consideration of the agricultural area immediately west and south of Kankakee, where limestone bedrock outcrops or lies below thin cover. Other areas have cover adequate to accommodate measures for protection of possible aquifers, (Exhibit 9).

Land slopes were not found to be prohibitively steep in any potential sandy-soil areas, although a portion of the Hopkins Park area, already eliminated for socio-economic reasons, is quite rugged.

The utilization of sludge will have some effects on environmental conditions, but will not preclude operations on any of the remaining area. Adverse effects on ground water are likely only in the southeastern portion of the sandy area. However, any significant aquifers would be developed for agricultural use, and the water quality would not be impaired for this purpose. Ground and surface-water resources could be protected for other sites, as discussed in Appendix F.

Selection of Most Promising Sandy-Soil Site

The screening process indicated that there are only three sandy soil areas, as shown on Exhibit 6, which have adequate acreage for a Phase 3 Site. These potential sites were selected for detailed evaluation to determine which is best suited for sludge utilization. The sites, designated as Coal City, Essex, and St. Anne, are described individually in the following sections.

Coal City. This site is located just west of Interstate Route 55 and about five miles beyond the Kankakee River bridge. It is served by the Santa Fe and the Gulf, Mobile and Ohio Railroads and includes lands in Mazon, Maine, and Braceville townships of Grundy County. The site is nearly 50 miles from the West-Southwest Plant. Coal mining and

corn farming have been the major activities of the area, although both underground and surface-mining operations are now idle.

The site is located on a flat plain of sandy loam underlain by sandy clay loam or clay loam, except for some silt-loam soils along the Mazon River, which flows through the area. Many of these soils have moderate moisture retention capacities. The site is underlain by coal, shale, and sandstone deposits, of Pennsylvanian Age, which outcrop at a few locations along the Mazon River. Unconsolidated materials are mostly 20 to 50 feet thick above the bedrock, with ground-water levels mostly 10 to 30 feet below the surface. Data are not available for a comprehensive evaluation to assess ground-water potential, but it is believed to be poor, because of the difficulty experienced by local villages in their attempts to develop adequate supplies.

The site includes properties of 134 owners, with an average land holding of 142 acres. The weighted averaged for corn production is 82 bushels per acre. The estimated current sales price of land is \$600 per acre.

Essex Site. This site is located about four miles south of the Village of Wilmington, and includes lands in Will and Kankakee Counties. It is nearly 50 miles from the West-Southwest Plant. Corn is the predominate agricultural crop. The Norfolk and Western (Wabash) Railroad crosses the area.

The site is located on level to rolling land, with some slopes in excess of eight percent on the dune ridges and near Horse Creek, which flows through the area. The soil texture varies from sandy loam to sand. The unconsolidated material is underlain by shale, sandstone, or dolomite. These bedrock materials are mainly at depths of 25 to 50 feet, although isolated outcrops occur. The depth to ground water

varies from about 12 feet to over 30 feet. Little information on ground water is available, but it appears unlikely that significant yields could be developed.

The site includes properties of 152 different owners with an average land holding of 129 acres. The weighted average for corn production is 68 bushels per acre. The estimated average sale price of the land is \$400 per acre.

St. Anne Site. This site is located between Illinois Route 1 and the Indiana State line, beginning about one half mile east of the Village of St. Anne. The site is nearly 60 miles from the West-Southwest Plant. It includes lands in St. Anne and Pembroke townships in Kankakee county and Beaverville and Papineau townships in Iroquois county. The site surrounds the Iroquois Game Refuge. Corn and soybeans are the principal farm crops. Both the Milwaukee and the New York Central Railroads cross this site and the Chicago and Eastern Illinois passes through St. Anne.

The site includes about 60 percent sandy soils, on flat to rolling topography. The remainder of the soils are fine textured silt loam, silty clay loam and clay. The depth of unconsolidated material range from 10 feet to over 100 feet, overlying permeable dolomite and limestone. The depth of ground water varies from 15 to 40 feet. The groundwater potential has not been assessed in detail, but existing well records indicate that it may be possible to develop water supplies adequate to satisfy estimated irrigation and domestic water demands.

The site includes the properties of 123 different owners with an average land holding of 149 acres. The weighted average for corn production is about 72 bushels per acre. The estimated average sale price of the land is about \$425 per acre.

Areas of Fine-Textured Soils

Two areas of fine-textured soils have been considered as a Phase 3 site, for purposes of comparison with the sandy-soil sites. Although the soils of Cook County are of that type, as indicated previously, there is no single area of 21,500 acres that is presently undeveloped in the county. Therefore, the sites selected for comparison were in nearby counties.

Of the two sites considered, the one designated as Manteno was considered to be less satisfactory than the other, designated as Andres. The Manteno site is further from Chicago, and adjoins a larger town (Manteno). Since the Manteno site has no compensating advantages, the Andres site was selected for detailed evaluation.

Andres Site. This site lies on both sides of U.S. Route 45 about 10 miles north of Kankakee, and it is located entirely in Will County. It is 35 miles from the West-Southwest Plant. Corn farming is the primary activity on this site.

The land is generally rolling, with only about 30 percent of the land being generally level. About 70 percent of the site has slopes of from 3 to 12 percent. The soil varies from silt loam to clay loam, with moderate to slow infiltration rates. The depth of unconsolidated material varies from 50 to 100 feet over dolomite. Water table depths are from 8 to over 30 feet below ground level.

The site includes properties of 164 different owners, with the average holding about 126 acres. The weighted average corn yield is about 87 bushels per acre. The estimated sale price of the land is about \$775 per acre.

PART TWO-EVALUATION OF SELECTED ALTERNATIVES

A detailed evaluation has been made of the three sandy soil sites and of the one fine-textured soil site, to determine which is best suited for implementation of the project. The alternative sites have been compared both by economic and by non-monetary criteria. Costs have been estimated on the basis of layouts and quantity take offs for the alternative agricultural sites and for the alternative conveyance methods and alignments. The estimates of individual cost components are valid for comparative site evaluation but should not be considered as final for project financing, since changes may occur during design studies.

Selection of alternative sites has been described in Part One of this chapter. The available alternatives for sludge conveyance to these sites are described and screened below.

Alternative Conveyance Methods

Several methods are feasible for the conveyance of sludge from the Calumet and West-Southwest Plants to the project area, including movement by truck, barge, railroad car or pipeline. The main features of each method are described below.

Truck Transportation

Trucking would provide great flexibility for sludge pick up or delivery but would require a great amount of manpower and equipment. Highway load limits would restrict truck loadings to about 6,000 gallons of liquid sludge, equivalent to about two tons of dry solids for a concentration of 8 percent solids. Truck hauling requires concentration of the

sludge to minimize haul movements and cost. Trucks would be well suited for Phase 1 and for the initial operation of Phase 2, because they can be placed in operation on short notice and provide additional flexibility for pick-up from either plant. However, they would be prohibitively expensive for any long term operation. In addition, trucks are probably less reliable than other methods because of their vulnerability to interruptions by adverse weather, labor disputes, or civil disturbances.

Barge Transportation

Barge conveyance offers some flexibility, particularly since the waterway passes quite near the Calumet and West-Southwest Plants. Large-unit capacity is available, with individual barges capable of hauling 420,000 gallons (140 tons of dry solids). Barge conveyance does require concentration of sludge solids. It has the further disadvantage of requiring docking and loading facilities at the plant, as well as docking and off-loading facilities on the waterway. Pumping and pipeline are required to reach from the waterway to the site. Barge operations are somewhat vulnerable to interruption.

Railroad Transportation

Each of the four alternative sites is located on or near a rail line which passes relatively close to one of the plants. Sludge conveyance is feasible by rail where "unit-train" operations can be employed, with the complete train unit operating on one railroad and committed to a single use. Moderate unit capacities are possible, using 24,000 gallon tank cars (eight tons of dry solids). Rail operations also are vulnerable to interruptions by labor disputes.

Pipeline Transportation

Pipeline conveyance is economical and highly reliable, since the buried facilities are not vulnerable to damage and, with automation, the pumping facilities are not subject to strike or other civil interruptions. However, pipelines have the disadvantage of being less flexible to meet possible changes in delivery location.

Comparison of Conveyance Alternatives

The selection of a conveyance method and route depends on the combined costs of site development and conveyance, as well as the returns from agriculture and other intangible factors. The conveyance costs comprise an important component in the overall-site comparisons, as discussed below. A summary of capital and annual cost for the conveyance alternatives to the Essex site, based on year 2015 requirements, is shown in Table III-1. The cost estimates for all conveyance-system alternatives are described in Appendix G.

Table III-1
SELECTED CONVEYANCE SYSTEM COSTS
(Costs in \$1,000)

Conveyance Method	Capital Cost ^{1/}	Annual Costs		
		Fixed	M & O	Total (Rounded)
1. Truck	9,100	575	9415	10,000
2. Barge	13,200	835	1255	2,100
3. Rail	9,100	575	1675	2,200
4. Pipeline	18,500	1170	605	1,800

^{1/} Including engineering, contingencies, overhead, and interest during construction.

Trucking costs are seen to be prohibitive for long-term conveyance, although their use for initial operation of the Phase 2 site would be justified, to expedite initiations of the sludge utilization program. Barge and railroad costs are higher than those for pipeline; however, they are based on quotations from commercial carriers which could well vary with more detailed preliminary investigation. Also, they include assumptions of the feasibility and cost of concentrating sludge which are not adequately refined. It is recommended that these costs be subject to further study, in order to make the rail and barge estimates as accurate as those for pipeline and to permit the weighing of reliability, flexibility, and maintenance and operation factors against a firm cost differential.

The pipeline costs have been based on the criteria established by the Sanitary District for these studies, including the use of 3.5 percent solids. Results of these studies suggest that more economical operations might be possible with solids concentrations increased to 5 percent or more, and further investigation of this point is recommended for the design studies.

Comparison of Alternative Sites

Comparisons of alternative sites were made on the basis of total construction and annual costs, tangible benefits and intangible factors.

Construction Costs

Costs have been estimated for the project, including land purchase, agricultural development and conveyance system. The gross Phase 3 area of 21,500 acres will provide a net area available for sludge utilization (after deducting roads and farmsteads) of 19,400 acres, which would accommodate the sludge production anticipated in the year 2015. Land purchase costs were determined by evaluating productivity of soils, assessed values and sale records, as described in Appendix H.

Agricultural development costs include land leveling, drainage, and where appropriate, irrigation systems. Costs have been based on layouts and quantity estimates described in Appendix H.

Conveyance system costs are described in detail in Appendix G and include pipelines, pumping stations, and other facilities. Barge costs include all facilities except the barges and towboats which would be leased. Railroad costs also were determined on the basis that the Sanitary District would lease the tank cars and locomotives.

The construction costs are summarized in Table III-2. The barge alternative to the St. Anne and Andres sites is not included because it is economically less attractive.

Economic Analysis

The details of computations of agricultural income and benefits are discussed in Chapter IV and Appendix D. The economic analysis has been made for a 6.0 percent interest rate and the amortization of all construction costs over 50 years. Annual costs include operating costs for power, replacement, maintenance operating personnel, and amortization charges for the investment. The net annual cost to the Sanitary District will be determined by subtracting from the total annual costs, a representative estimate of the Sanitary Districts' share of income from crop production. The income estimate is valid for this comparison, but it should be studied further in the design phase, before a decision is taken on the division of income with the farmer.

Selection of Phase 3 Site

The studies reveal that irrigation will be required to maintain a satisfactory agricultural operation and realize the potential for upgrading of the sandy soils. While it would be possible to apply sludge

Table III-2

SUMMARY OF CONSTRUCTION COSTS FOR
PROJECT DEVELOPMENT

(Costs in \$1,000)

Alternative Transport Methods	SITE				
	Andres	Coal City	St. Anne	Essex with Irrigation	Essex without Irrigation
Pipeline Alternative:					
Transport System	12,600	20,700	19,700	18,500	18,500
Site Development	15,900	20,800	21,300	19,600	14,900
Land Purchase	<u>16,000</u>	<u>14,100</u>	<u>11,300</u>	<u>8,900</u>	<u>8,900</u>
Total Capital Cost (rounded)	45,000	56,000	52,000	47,000	42,000
Rail Alternative:					
Transport System	10,700	8,800	11,000	9,100	9,100
Site Development	15,900	20,800	21,300	19,600	14,900
Land Purchase	<u>16,000</u>	<u>14,100</u>	<u>11,300</u>	<u>8,900</u>	<u>8,900</u>
Total Capital Cost (rounded)	42,000	44,000	43,000	38,000	33,000
Barge Alternative:					
Transport System		12,100		13,200	13,200
Site Development		20,800		19,600	14,900
Land Purchase		<u>14,100</u>		<u>8,900</u>	<u>8,900</u>
Total Capital Cost (rounded)		47,000		42,000	37,000

on sandy-agricultural land, there will be some problems involved if supplemental water is not applied.

The first problem is the necessity for more extensive measures for protection of ground water, because of lesser potential for removing nutrients by crops. The second problem, which is more serious, is that without irrigation there will be agricultural failures (50 percent of optimum-crop production) in an estimated 6 out of 10 years. There is presently a high incidence of failures, but it is believed vulnerability to drought failure would increase without irrigation because of high fertility and salt build-up in the soil from sludge application.

Because of the importance of irrigation, it has been included in the cost and benefit comparisons for all of the sandy-soil sites. In addition, at one of the sandy-soil sites (Essex), an estimate has been made of the cost and benefits without irrigation. Irrigation will not be essential for maintenance of successful agriculture with sludge application at the fine-textured soil site and has not been included in the comparison for the Andres site.

The results of the economic comparisons are shown in Table III-3. In addition to these economic considerations, certain socio-economic factors need to be considered in the selection of a site. These include such factors as population, farm ownership, size of farms, value of land and improvements, existing productivity and land use, etc. These data have been evaluated and are presented in Table III-4. The sources of these data have been footnoted in Appendix E.

From the data in Table III-3, it is apparent that the Coal City and St. Anne sites are significantly higher in cost than the Essex site, with less net benefits from application of sludge. There are no technical

Table III-3

ECONOMIC COMPARISON OF ALTERNATIVE PHASEPHASE 3 SITES

<u>Item</u>	<u>Andres</u>	<u>Coal City</u> (with irrigation)	<u>St. Anne</u> (with irrigation)	<u>Essex</u>	
				<u>With</u> <u>Irrigation</u>	<u>Without</u> <u>Irrigation</u>
Estimated Cost of Land Purchase per Acre <u>1/</u>	\$ 775	\$ 600	\$ 425	\$ 400	\$ 400
Construction Cost <u>1/</u>	45,000,000	56,000,000	52,000,000	47,000,000	42,000,000
Average Annual Cost <u>2/</u>	3,800,000	4,700,000	4,500,000	4,200,000	3,700,000
Average Cost per ton sludge, excluding digestion <u>3/</u>	8.80	10.90	10.50	9.80	8.60
Total Cost per ton with digestion <u>4/</u>	21.30	23.40	23.00	22.30	21.10
Net Annual Agricultural Income with Project <u>5/</u>	837,000	1,150,000	1,150,000	1,150,000	651,000
Increase in Net Agricultural Income due to Project	-48,000	339,000	546,000	581,000	82,000
Annual Increase in Indirect Benefits <u>6/</u>	-39,000	.278,000	448,000	476,000	67,000

- 1/ Assumes use of pipeline and includes land, pipeline and pumping facilities, farm development, contingencies, engineering, overhead, and interest during construction.
- 2/ On basis of 6 percent interest rate and amortization of all construction costs over 50 years, and including maintenance and operation of sludge and irrigation water distribution.
- 3/ Without deduction of portion of agricultural income to be allocated to District,
- 4/ Based on cost of \$12.50 per ton of undigested solids for Imhoff tank and heated digestion.
- 5/ To be divided between Sanitary District and farmers on basis of decisions yet to be made.
- 6/ Based on 82 percent of the annual increase in net agricultural benefits with the project.

Table III-4

SUMMARY OF SOCIO-ECONOMIC CHARACTERISTICS

<u>Item</u>	<u>Sites</u>			
	<u>Andres</u>	<u>Coal City</u>	<u>St. Anne</u>	<u>Essex</u>
<u>Population (1960)</u>				
Within Sites	307	314	325	354
Within 3 Miles of Sites	3020	4500	6070	2340
<u>Farm Characteristics (1966-67)</u>				
Idle Land - %	10	12	21	26
Dwelling Units - No.	86	95	90	100
Land Owners - No.	164	134	123	152
Ave. Area Owned - Acres	126	142	149	129
Farm Operators - No.	86	95	90	100
Ave. Area Farmed - Acres	292	248	256	242
Full Owner Operators - %	44	44	28	37
Part Owner Operators - %	20	20	21	22
Tenants - %	36	36	51	41
<u>Land Value, Based On</u>				
Assessed Value ^{1/} (\$)	732	644	517	406
Land Productivity (\$)	770	597	426	400
Recent Sales (\$)	-	494-803	170-600	250-425
Highway Purchases (\$)	700	-	-	-
Value Used (\$)	775	600	425	400

^{1/} Includes value of farm improvements and land, adjusted to present worth.

advantages to either the Coal City or St. Anne sites, nor does Table III-4 reveal any socio-economic advantages to these sites, to counteract the cost advantage of Essex. Therefore, the selection of the Phase 3 site can be narrowed to a comparison of the Essex and Andres sites.

Table III-3 indicates that total annual agricultural net income will be increased at Essex by \$499,000 if irrigation is included, compared to an increase in annual costs of \$500,000. Thus, the increased annual costs of irrigation just balances the increased benefits. In addition, irrigation involves higher construction expenditures. Therefore, irrigation is justified only if it serves other than economic objectives. One of the basic objectives is to apply sludge in a manner which will produce a maximum upgrading of land capabilities. As indicated previously, this is possible only with irrigation. Therefore, it is concluded that irrigation at the Essex site must be included in the comparison between the Essex and the Andres site.

There is no significant advantage in the cost of sludge disposal to either the Essex or the Andres site. The greatest advantage of the Essex site is that it will provide a great increase in agricultural production and thus a great economic impact on the area involved. Table III-3 indicates that at Essex, the total increase in net benefits to be shared by the farmer and the District from agricultural production will be approximately \$581,000 per year. In addition, there will be indirect benefits in the area of approximately \$476,000 per year. On the other hand, if the Andres site is used, there would be a slight decrease in net income from production and in indirect benefits. Thus, the Essex site provides very significant values as a reclamation project, as compared to no upgrading of the agricultural economy through use of the Andres site.

There are other advantages to the Essex site. It would have greater ease of purchase due to a higher percentage of idle land and fewer owner-operators. It requires less extensive measures for protection of surface water. There are fewer problems of dislocation of residents, since there are a greater percentage of existing tenant operators. The sandy soils are more favorable for crop management and corrective measures can be more easily applied in the event of problems of soil-plant relationships. Finally, the selection of the Essex site allows more flexibility in the method of transportation of sludge to the project area, since barge, rail, and pipeline are all feasible alternatives; whereas barge transportation to the Andres site is not feasible, and rail connections are difficult.

The major disadvantage of the Essex site is the possibility of legal entanglements in obtaining a water supply for irrigation. The maximum rate of water application required during the peak drought period could be as high as 320 cfs, which is only slightly less than the normal minimum summer flow in the Kankakee River. This relationship to water availability is much less serious if the supply is obtained from the junction of the Kankakee River and Des Plaines River, where the minimum summer flow is generally at least 3,000 cfs. Because of this, the cost estimate for the Essex site has included the provision for a pipeline to transport water from the junction of the two rivers to the site.

It is highly unlikely that the use of 320 cfs, even at times of minimum flow, would impair the riparian rights of any owners downstream from the junction of the Kankakee and Des Plaines Rivers. Despite this, there is a possibility of legal involvements in the use of such water. If such legal involvements become serious there is the further possibility

of providing storage reservoirs near the Essex site, to hold surplus flows which could be diverted from the Kankakee River during times of high runoff, for use during the irrigation season.

There are some advantages to the Andres site, though most of them are relatively minor. It is possible, though no certain, that it could be brought into operation a year sooner than the Essex site because less time is needed for land development. The Andres site is all in one county (Will) and therefore minimizes administrative problems. Initially, the Andres site will require less extensive measures to protect ground water, because of a greater soil storage capacity for nutrients. It also is close to the Sanitary District for purposes of management and is more accessible for public viewing of project operations that can be derived from the project. Lastly, it has a slightly lower construction cost, although its net annual cost is not significantly different.

On the basis of all factors, the Essex site is recommended for land acquisition. By far the most important consideration leading to this recommendation is the upgrading of crop production capabilities of the Essex site and, therefore, the positive economic impact it will have on the area. Because of this, a better acceptance by the local interests is expected. In contrast to this, a negative economic impact is anticipated through use of the Andres site. Other advantages and disadvantages of the two sites seem to about offset each other.

It is recommended that land acquisition be carried out on the basis of giving the present owners the opportunity of leasing the land for operation in accordance with methods of sludge application that will be controlled by the District. This is the same procedure recommended for the Tinley Park site. This method will provide the least disruption to the residents of the area and should gain the most widespread local acceptance. It also will provide competent farmers to carry out the agricultural project.

Chapter IV

AGRICULTURAL ECONOMICS

The land reclamation program at the Essex site will produce multi-purpose benefits in the following ways: (a) annual net farm income will increase due to increased agricultural productivity; (b) tax revenues will increase in Will and Kankakee Counties due to increased land values; (c) merchants in the area will benefit from the increased purchasing power of the farmers; and (d) the Sanitary District will benefit by a reduction in cost of sludge disposal.

The determination of costs of disposal of sludge is a relatively straight-forward matter. As indicated in Chapter III, these costs are estimated to be reduced by about 60 percent, from about \$50 per ton to \$20 per ton. Thus, the economic justification for the recommended procedure for sludge disposal is quite obvious. However, the procedures for computing agricultural benefits are much more complicated and less obvious.

Because of the great importance of demonstrating the very real agricultural benefits that will accrue to the farmers and the local community, the remainder of this chapter concentrates on the method of computing these benefits. The chapter is concerned only with the derivation of benefits--the use of these benefits for purposes of evaluation of alternative sites has been demonstrated in Chapter III. Only a broad description of the benefit computations is given in this chapter--further details are given in Appendix H.

Summary of Results

The general approach used to estimate crop benefits has been to estimate the net income from production under existing conditions of development and projected future management without the project and under development with the land reclamation project. The difference between the two represents the increase in benefits due to the project. Allowances are made for the farmer's costs and improvement in farming methods. The computations have included estimates of direct benefits to the farmers and the District, as well as indirect benefits to the economy of the general area. The estimates have been based on the 1967 level of farm costs and prices.

The results of the benefit analyses for the Phase 2 site (Tinley Park) are summarized in Table IV-1. For the Essex site, analyses have been made with and without irrigation, to demonstrate the value of irrigation on sandy soil.

On the Tinley Park, Phase 2, site, heavy sludge loading during the first four years of operation will prevent cropping on varying amounts of land each year (Chapter II). Starting the fifth year presumably the Essex site would be in operation, and the sludge loadings on the Tinley Park site would be reduced to around 10 tons per acre. The total cropped area of 1650 acres would be available for normal agricultural production.

Estimates of the benefit analyses for Tinley Park for the first four years are summarized in Table IV-2. During this period, net annual agricultural income would average \$73,000 which is a decrease from about \$86,000 estimated for present conditions. However, beginning the

Table IV-1

SUMMARY OF BENEFIT ANALYSES

	<u>Andres site</u>	<u>Phase 3 Sites</u>		<u>Essex site</u>	
		<u>Coal City site</u>	<u>St. Anne site</u>	<u>with irrigation</u>	<u>without irrigation</u>
Gross Annual					
Agricultural Income	\$1,857,000	\$2,593,000	\$2,593,000	\$2,593,000	\$1,474,000
Annual Cost of Production <u>1/</u>	<u>1,020,000</u>	<u>1,443,000</u>	<u>1,443,000</u>	<u>1,443,000</u>	<u>823,000</u>
Net Annual Agric- ultural Income	\$ 837,000	\$1,150,000	\$1,150,000	\$1,150,000	\$ 651,000
Increase in Net Annual Income due to Project	-48,000	339,000	546,000	581,000	82,000
Increase or Decrease in Indirect Benefits to Community	-39,000	278,000	448,000	476,000	67,000

1/ Includes operator's labor and management, real estate taxes, and other operating costs.

fifth year net income from the total cropped area would be increased to about \$100,000, because of increased yields due to land improvements and the beneficial fertilization effects from the sludge.

Table IV-2

SUMMARY OF BENEFIT ANALYSES

Phase 2 (Tinley Park)

<u>Item</u>	<u>During Accelerated Application</u>	<u>During Normal Application</u>
Gross Annual Agricultural Income	\$161,000	\$216,000
Annual Cost of Production	88,000	116,000
Net Annual Agricultural Income	73,000	100,000
Increase or Decrease in Net Income due to Project	-13,000	+14,000
Increase or Decrease in Indirect Benefits to Community	-11,000	+11,000

Description of Benefit and Cost Computations

Crop Production

The estimate of crop production, with and without sludge utilization was the first step in benefit computations.

The estimate for conditions without sludge application was based on the assumption that there would be no irrigation in the future, that current cropping patterns and cropped acres would prevail, and that normal increases in the yields due to normal improvements in farm

practices would occur. These estimates were made by projecting crop yields on the basis of U. S. Government forecasts^{1/}.

Projected yields with sludge application were based on anticipation that the District would own the land and control the cropping pattern and method of sludge application. The lands would be leased on a long-term basis to individual farmers, in family-sized units. The District would provide professional advice on selection of seeds, use of herbicides and other similar matters, but the management decisions on these latter matters would rest with the farmer.

The yields per acre with sludge application were based on University of Illinois data on yields for well-managed farms with better soils which have an adequate supply of water. The area cropped with sludge utilization was assumed to increase to 90 percent at the sites with sandy soils (Coal City, St. Anne, and Essex), compared with their present cropped areas of 88, 79, and 74 percent, respectively. At the Andres site, where 90 percent of the land is presently cropped, the cropped area with the project was assumed to remain the same.

The estimates of crop production on the Phase 3 sites are summarized in Table IV-3 based on a future cropping pattern which was adopted to reflect a minimum disruption of existing markets and to accommodate sludge utilization, as described in Appendix D.

^{1/} "A Look Ahead for Food and Agriculture" by R. F. Daly and A. C. Egberts, Economic Research Service, U. S. Department of Agriculture.

Table IV-3

ESTIMATES OF ANNUAL CROP PRODUCTION

(Yields and Production in Bushels, Except in Tons for Alfalfa)

<u>Crop</u>	<u>Without Project</u>			<u>With Project</u>		
	<u>Yield per Acre</u>	<u>Number 1/ of Acres</u>	<u>Total Production (1,000)</u>	<u>Yield per Acre</u>	<u>Number 1/ of Acres</u>	<u>Total Production (1,000)</u>
<u>Andres Site</u>						
Grain Corn	100	9,680	968	120	6,390	767
Soybeans	33	5,800	191	40	4,260	170
Wheat				50	970	49
Oats	66	3,870	255 ^{2/}	80	970	78
Alfalfa and Grass ^{3/}	---	---	---	4.0	6,760	19
<u>Coal City Site</u>						
Grain Corn	94	9,460	889	140	9,680	1,355
Soybeans	31	5,590	173	45	4,840	218
Wheat				60	970	58
Oats	62	3,870	240 ^{2/}	90	970	87
Alfalfa	---	---	---	4.5	1,940	8.7
<u>St. Anne Site</u>						
Grain Corn	77	8,390	646	140	9,680	1,355
Soybeans	26	5,160	134	45	4,840	218
Wheat				60	970	58
Oats	51	3,440	175 ^{2/}	90	970	87
Alfalfa	---	---	---	4.5	1,940	8.7
<u>Essex Site (with Irrigation)</u>						
Grain Corn	78	7,960	621	140	9,680	1,355
Soybeans	26	4,730	123	45	4,840	218
Wheat				60	970	58
Oats	52	3,220	167 ^{2/}	90	970	87
Alfalfa	---	---	---	4.5	1,940	8.7
<u>Essex Site (without Irrigation)</u>						
Grain Corn	78	7,960	621	80	9,680	774
Soybeans	26	4,730	123 ^{2/}	27	4,840	131
Oats	52	3,220	167 ^{2/}	48	3,880	186

^{1/} Areas shown are based on a gross project area of 21,500 acres with 10 percent in roads, ditches, farmsteads, etc. and the remainder not shown in grass with the project and idle land without the project.

^{2/} Area shown in oats includes other crops presently grown.

^{3/} Includes 4,070 acres of grass with yield estimated equivalent to 2.0 tons of alfalfa per acre.

For the Tinley Park site (Phase 2), a cropping pattern of 50 percent corn and 50 percent soybean was assumed, with yields with and without the project. The same as estimated for the heavy-textured soil typical of the Andres site.

Income

Estimates of farm income were obtained by multiplying the projected production by the current market price. The values used were as follows:

Corn	-	\$1.25	per bushel
Soybeans	-	\$2.80	per bushel
Wheat	-	\$1.60	per bushel
Oats	-	\$0.75	per bushel
Alfalfa	-	\$15.00	per ton

Cost of producing each crop was based on actual records kept by 36 cooperative farmers who belong to the Illinois Farm Bureau Farm Management Service. The farms were distributed by size, type and quality of soil in Western and Central Illinois. Important differences among the farm records were: (1) volume of business; (2) local weather, insect, and disease conditions; (3) management ability of the operator; (4) capital investment; (5) land use and fertility practices; (6) size of farm and quality of soil and (7) proportion of tillable land. Farms were selected from this group which most nearly represent the farms in the sites under study. Real estate taxes were assumed to be an item of cost in both computations, on the assumption that the Sanitary District would be required to pay taxes if it obtained ownership.

The results of the income computations are given in Table IV-4.

Table IV-4

ESTIMATES OF ANNUAL AGRICULTURAL INCOME
(\$1,000)

<u>Site</u>	<u>Without Project</u>			<u>With Project</u>			<u>Diff- erence</u>
	<u>Gross Farm Income</u>	<u>Cost of Production</u>	<u>Net Farm Income</u>	<u>Gross Farm Income</u>	<u>Cost of Production</u>	<u>Net Farm Income</u>	
Andres	\$1,936	\$1,051	\$885	\$1,857	\$1,020	\$837	\$-48
Coal City	1,776	965	811	2,593	1,443	1,150	339
St. Anne	1,314	710	604	2,593	1,443	1,150	546
Essex	1,246	677	569	2,593	1,443	1,150	581
Essex (w/o irrig.)	1,246	677	569	1,474	823	651	82
Tinley Park (Accelerated)	187	101	86	161	88	73	-13
Tinley Park (Normal)	187	101	86	216	116	100	14

The decrease in projected net farm income, as well as costs, on the Andres site is due to the change in cropping pattern from corn and soybeans to corn, soybeans, wheat, oats, alfalfa, and grass. Corn and soybeans have higher net incomes per acre and higher costs of production than wheat, oats, alfalfa, and grass, but the latter four crops are required to assure continuous application of sludge during extreme climatic conditions. The decrease in projected net farm income on the Tinley Park site will result during the initial four years of operation while portions of the area are receiving heavy sludge application. Net agricultural returns per year beginning the fifth year, with sludge

applications of only ten tons per acre, would amount to about \$100,000 which would represent an increase above present conditions of about \$14,000 per year. The extensive grass areas are not required because the total tonnage of sludge used at Tinley Park will not be great. It has been assumed that this sludge could be stored or diverted to the Phase 3 site during wet periods.

Annual Costs of Reclamation Project

Capital costs of Phase 3 have been given in Chapter III and are developed in detail in Appendix H. The annual costs in investment in the sludge transportation facilities, the land and the land development have been based on amortization over a 50-year period at 6.0 percent interest. The annual costs include operation and maintenance costs for the transportation and sludge distribution facilities, but do not include the farmers cost of production and real estate taxes, which have been included as a part of the net farm income estimate.

The net annual costs of alternative Phase 3 sites are given in Table IV-5.

Table IV-5

NET ANNUAL COSTS OF LAND RECLAMATION

<u>Site</u>	<u>Capital Cost of Development</u>	<u>Annual Cost of Development</u>	<u>Net Income</u>	<u>Net Annual Cost</u>
Andres	\$45,000,000	\$3,800,000	\$ 837,000	\$2,963,000
Coal City	56,000,000	4,700,000	1,150,000	3,550,000
St. Anne	52,000,000	4,500,000	1,150,000	3,350,000
Essex (with irrig.)	47,000,000	4,200,000	1,150,000	3,050,000
Essex (w/o irrig.)	42,000,000	3,700,000	651,000	3,049,000

The capital and annual costs for Phase 2 have been developed, Appendix H, for the initial two years of operation, but the costs for subsequent years will depend on the conveyance system selection.

Distribution of Net Agricultural Income

The above net annual costs do not reflect directly the cost to the District of sludge disposal. A significant portion of the increase in net income from agricultural production should be allocated to the farmer, to provide incentive for a successful agricultural operation and to pass on the benefits to the community.

Traditionally, the division of income between the owner and tenant in Illinois has varied. Frequently the division has been 50 percent to the owner and 50 percent to the tenant. However, there is sufficient variation from this to cause the average for the state to be 42 percent for the owner and 58 percent for the tenant.

A study has not been made of an appropriate division of income on the lands of the sludge utilization project. There are several factors which would influence the decision on terms of lease for farm operation. Tending toward a high share for the tenant is the desire to give the farmer an increased incentive to sell his lands and to give high indirect benefits to the community. On the other hand, it is presumed that the District will pay costs of sludge and irrigation water distribution, which is a cost to the owner that is not reflected in the Illinois average values for the division of farm income.

For demonstration purposes, a computation has been made of the net income per acre and the total benefits that would accrue for the Essex Site, with irrigation, under various divisions between the owner and lessee. These results are shown in Table IV-6.

Table IV - 6

RESULTS OF ALTERNATIVE METHODS OF DIVIDING BENEFITS

Essex Site	Owners Share			Lessee Share ^{1/}			Annual Indirect Benefits to Community	Difference in Cost to District of Sludge Disposal, from 50-50 Split	
	Percent of Total	Annual Net Income per Acre	Total Project Net Income Annually	Percent of Total	Annual Net Income per Acre	Total Project Net Income Annually		Per Ton of Sludge	Total per Year
Without Project	40	\$12	\$228,000	60	\$18	\$341,000	-	-	-
With Project	60	36	690,000	40	24	460,000	260,000	-0.27	\$-115,000
With Project	50	30	575,000	50	30	575,000	296,000	0	0
With Project	40	24	460,000	60	36	690,000	332,000	0.27	115,000
With Project	30	18	345,000	70	42	805,000	368,000	0.53	230,000
With Project	20	12	230,000	80	48	920,000	404,000	0.80	345,000
With Project	10	6	115,000	90	54	1,035,000	440,000	1.06	460,000
With Project	0	0	-	100	60	1,150,000	476,000	1.33	575,000

^{1/} In addition to the income per acre shown, a return to the farmer for management of approximately \$15 per acre has been included in the cost of production and a cost of approximately \$20 per acre for an irrigation system and equipment has been charged to the Sanitary District.

Chapter V

PRELIMINARY DESIGN OF PHASE 3 PROJECT

Phase 3 will provide for the utilization of digested-sewage sludge for the production of high-return crops on the Essex Site. The project will include 19,400 net acres of sandy soils on which crop production will be increased, by 75 percent for corn, over projected yields without the project. The land surface will be graded to control drainage and runoff, and sub-surface and area drainage will be improved. An irrigation and sludge application system will be installed. A public water system will be provided throughout the project area for fire protection and domestic water needs.

The project will be operated under a system which will be designed and managed to produce increased crop yields without nuisance or hazard to the area residents. Applications will be made to provide for optimum utilization, by the crops, of the nutrients and trace elements contained in the sludge. Runoff and drainage from the area will be controlled to avoid adverse effects upon down-stream water quality.

Phase 3 Project Components and Operation

The main components of the Phase 3 project have been sized, located and designed to the degree required for the comparative analysis of project site and conveyance-system costs. The costs are valid as a basis for selection of the recommended Phase 3 site and conveyance

system, which is the objective of this study. The estimates give an adequate indication of project costs for comparison of alternatives, however, they do not represent the most economical sizing for each item or an adequate basis for project financing. These functions will be the subject of the next phase of engineering investigations and are discussed in Chapter VII.

Sludge Conveyance System

Collection. The first link in the conveyance system will be the in-plant facilities for sludge collection, holding and, if required, processing. Both the Calumet and West-Southwest plants will need to retain a portion of the present lagoons, to provide holding capacity for seasonal fluctuations of production or for periods of operational outage. Mechanical concentration may be necessary to provide sludge at the optimum solids concentration for economical conveyance.

Pipeline and Pumping. If the pipeline is ultimately selected as the means of sludge transportation, it would be located as shown on Exhibit 7. The probable sizes would include a 24-inch pipe from the West-Southwest Plant, joined near Palos Heights by a 14-inch pipe from Calumet, and continuing as a 24-inch pipe to the site. Public rights-of-way can be occupied for much of the route, but right-of-way purchase is justified for the mainline south of Frankfort by the cost saving of the diagonal location. The pipeline would operate in separate reaches, each terminating in a pump forebay to minimize hydraulic problems.

Pumping stations will be located at both treatment plants and at points where required by the head loss or terrain along the pipeline.

Based on the delivery schedule shown in Exhibit 1, the initial installed capacity would be 12.0 mgd for main-line pumps. The capacity for the reach from the Calumet Plant to the main line would be 2.6 mgd and that from the West-Southwest Plant would be 9.4 mgd.

Pumping station locations were not determined during this study. Comparative cost estimates have been based on a total of six pumping stations, with three operating units and one stand-by at each station. An operating load factor of 95 percent has been assumed. Equal operating heads of about 325 feet were assumed for all stations, based on using a 14-inch diameter pipeline for the Calumet branch and a 24-inch diameter pipeline elsewhere. An average friction coefficient of Hazen-Williams $C=90$ was derived to estimate total pumping head.

Land Reclamation System

Cropping Pattern. A basic consideration in the preliminary design of the land reclamation system is the crops which will be grown on the reclaimed lands. Final determination of the crops to be grown will be based on the results of University of Illinois studies, which are presently starting, therefore an interim cropping pattern has been determined for this study.

In determining the interim cropping pattern the factors that were considered included; climate, soils, markets, transportation facilities, present practices, nutrient utilization and sludge application requirements. Table V-1 shows the cropping pattern used for the Essex site.

Table V-1

CROPPING PATTERN

<u>Crop</u>	<u>Percent of Net Area</u> <u>^{1/}</u>
Corn	50.0
Soybeans	25.0
Small Grains	10.0
Alfalfa	10.0
Grass (Reclamation Area)	5.0

Irrigation. As stated in Chapter III, irrigation is considered essential to a well managed land reclamation project at the Essex site. An important factor in arriving at this conclusion is the probability of crop failure without irrigation.

Rainfall data for the Essex area shows a probability of 30 and 60 percent of receiving a total of one inch rainfall during July and August for a one and two week period respectively. With the computed July and August water requirements for corn, the available moisture holding capacity for a typical Essex area soil and the above rainfall probabilities corn yield reductions of about 50 percent would result at least 40 percent of the time . Because of the high nitrogen quantities added by the sludge (causing increased leaf growth and, therefore, a greater water requirement) this failure incidence may be increased.

A second factor, which is directly related to the low crop yields, is the removal of nutrients from the area. At the Essex site an increase

^{1/} Based on a net cropped area of 19,400 acres.

of about 75 percent in nitrogen removal results with irrigation over the project without irrigation.

Water Requirements. The amount of supplemental water required for irrigation of crops shown in Table V-1 was computed using an empirical method (the modified Blaney-Criddle method) developed for this purpose. Using rainfall and temperature records from the climatological station at Kankakee, Table V-2 shows the irrigation diversion requirements resulting for the months of May, June, July and August. The amount of water supplied by sludge and the drain water reuse system is also shown.

Table V-2

ANNUAL IRRIGATION DIVERSION REQUIREMENTS
(For a net area of 19,400 Acres)

<u>Month</u>	<u>Diversion Requirement</u> (Ac Ft)	<u>Supplied by Sludge</u> (Ac Ft)	<u>Supplied by Reuse System</u> (Ac Ft)	<u>Required From Irrigation Water Source</u> (Ac Ft)
May	1,370	688	137	545
June	6,610	665	661	5,284
July	14,370	688	1,437	12,245
August	<u>10,260</u>	<u>688</u>	<u>1,026</u>	<u>8,546</u>
Total	32,610	2,729	3,261	26,620

As shown in Table V-2 the amount of water supplied by sludge is only about eight percent of the diversion requirement during the irrigation period. The amount shown as required from an irrigation water source is the quantity needed for the second driest year out of ten. An average year requirement would be ten or fifteen percent less than this.

The peak period irrigation requirements were computed using the soil conservation service method. This results in a peak demand flow of one cubic foot per second per fifty acres of irrigated land. Using this flow as a basis for the irrigation design, a peak period diversion flow of 320 cubic feet per second results for the Essex site.

Site Development. The land reclamation system development at the Essex site is shown on Exhibit 10. It will include land leveling, a surface and tile drainage system, a sludge and irrigation distribution system and an irrigation water diversion system.

The land will first be leveled and graded to slope towards the tile drain system and to provide embankments on which the sprinkler irrigation equipment can operate. This also will provide storage for rainfall and for possible overland runoff during winter operations.

The drainage system will consist of tile lines one half mile long at 1300 foot intervals, with the tile line outletting into open channels spaced at one mile intervals. In addition, perimeter ditches will be provided to prevent groundwater movement outward from the site. Gates on the open channels and small holding reservoirs will provide containment during periods of low stream flow and will provide storage for the irrigation reuse system.

The sludge distribution system will consist of a main pipeline extending from near Custer Park south across the area and laterals extending at one mile intervals from the main pipe to the site boundaries.

Sublateral pipelines will extend in both direction from the lateral across the cropped area. The main sludge pipeline (24 inch dia.), will carry only sludge but the lateral and sublateral system will be used for both sludge and irrigation water. The laterals will be 12 to 30 inch diameter pipes, and the sublaterals will be 6-inch diameter pipes.

The irrigation distribution system will consist of a main canal extending from the water source to and across the area and the lateral and sublateral system. Booster pumps will be located at points where the lateral pipelines cross the main canal and the water will be pumped from the canal into the pipeline system.

Two possible sources for the Essex area irrigation water supply are the Kankakee and the Illinois rivers. A study of the Kankakee river flow at Wilmington showed that about 2500 acre feet of storage would be required once in ten years in order to maintain a minimum flow of 350 cfs below the irrigation diversion point. Because of this and of the possibility of legal restrictions, the irrigation diversion point was assumed to be at the confluence of the Des Plaines and Kankakee rivers. The diversion system would consist of a pumping plant at the Dresden Pool with a pipe and open canal to convey the water to the project area. A second pumping plant would be required near the project site to convey the water across the area.

Sprinkler equipment will be used to distribute the irrigation water because of the high infiltration rates of the sandy soil. When applying the sludge the sprinkler system will be used except during the growing season, at this time surface application will be used for corn and soybeans only. Preliminary design of the sludge and irrigation system

is such that either surface or sprinkler methods can be used. The field and pipeline layouts were made assuming that a "big gun", automatically towed sprinkler would be used for the sprinkler system and that gated pipe would be used for the surface system.

A strip of trees will be provided around the site for esthetic purposes. In addition trees for windbreaks will be required to give the sprinklers a good distribution pattern on windy days.

Other Design Aspects

Domestic Water Supply System. A water supply system will be constructed to insure a safe and adequate supply of water to farmers participating in the reclamation project. The system includes a transmission line, treatment plant and distribution system. The Kankakee River would be used as the supply source.

Vector Control. While there is no evidence that either insects or rodents would be attracted by the sludge, extensive spray and fumigation efforts will be included in the project operations.

Wildlife Management. The project includes features favorable for the production and hunting of up and-game birds. Tree or other screening plantings are proposed for the project boundaries and the vegetative cover will comprise an assortment of row-crops, grass areas and woodlots. These conditions attract birds and provide good hunting which could be enhanced by the coordinated management of such a large area and made available for hunting by the general public.

Management of the Agricultural Operation

It is recommended that the Sanitary District hire a farm management staff or retain a farm management firm to supervise the operation of the reclamation program. Professional advice from farm management firms is available for routine farm operations, but this might need to be supplemented by agricultural advice from specialized consulting firms familiar with this type of project. This would place the agricultural management in professional hands and avoid the staffing and management problems of operating the farm with Sanitary District personnel.

It is recommended that the Sanitary District purchase the farm lands because the farmers will be required to operate in a manner which is somewhat more restrictive than the normal farm-tenant agreement. It also is recommended that the land be leased back to the present owners or operators, where possible, to minimize dislocation problems. The lease provisions should allow the District to specify details of crop selection, sludge application rates and time and other controls to assure that safe, efficient and productive results are obtained. At the same time the lease should provide sufficient guarantees to the farmer to encourage him to enter the leasing agreement. The details of the leasing agreement should be developed by consultation between the purchasing agent and agricultural specialists of the consultants staff.

Chapter VI

ENVIRONMENTAL CONSIDERATIONS

All aspects of the project have been examined to determine what potential changes to the environment may result from the utilization of sludge for agricultural production. The study was directed particularly at the possible effects on the public health of the residents and on the natural resources of the area. In addition, the effects on the social and economic features of the environment were studied and are discussed in Chapter IV. The recommended development plan includes features designed to prevent any detrimental effects on the environment which might result from project implementation at the Essex Site.

Public Health

Pathogenic Organisms

The public is naturally concerned with the health aspects of application of sewage residues on soil because of the presence of pathogenic organisms in untreated sewage. Although the numbers of bacteria and viruses are reduced greatly by treatment and sludge digestion, a number of pathogenic organisms may be present in sludge applied to fields. Very little information has been found to provide a basis for forecasting the pathogens likely to be present in the sludge. It appears that virus may be inactivated, but experimental verification will be required. None of the users of sewage sludge for soil conditioning and fertilizer have reported any particular health problems, however, none have stated the degree of medical control for the work involved.

It is recognized that some health hazard may exist, and it is recommended that project operations include, as a precautionary measure, a program of physical examinations, immunization and other appropriate public health measures. Finally several alternatives are available for sterilization of virus, if that step should prove necessary.

Dissolved Minerals

Preventive measures are required to confine the effects of some minerals dissolved in the sludge, principally nitrogen and phosphorous. Metal ions are normally tied-up chemically to the soil minerals and should not cause any hazard. Other dissolved minerals are either harmless or present in very low concentrations. Studies by the University of Illinois should identify any potential problems with leached minerals, including trace minerals such as boron.

Sludge application rates, crop selection and operation of constructed facilities will be coordinated to prevent nitrogen-pollution problems. The sludge contains significant levels of nitrogen, of which nearly 33 percent is in a form (ammonia) which is readily soluble and can be rapidly mineralized to the nitrate form. Nitrate is required by the crop, but it is not held in the soil and will leach to the ground water when available in excess of crop needs. Excessive nitrates in drinking water may present a health problem.

For this reason, the installation of a new water system drawing its supply from surface water is proposed to replace existing well systems. The crop needs and conversion rate of nitrogen to nitrate in the soil are difficult to predict. Studies by the University of Illinois are in progress and should add to the knowledge in this area. In addition to the water supply system, the recommended development plan will include protective measures such as the following to assure that hazards

are prevented, and stream quality criteria are not exceeded:

- (a) Confinement of ground-water movement to prevent outflow;
- (b) Retention of ground and surface-water drainage;
- (c) Provisions for re-use of drainage water; and
- (d) A ground and surface water monitoring system to establish present concentrations of chemicals in the waters and to detect any changes from those concentrations.

The public-water system will provide more reliability and fire-protection potential than the present individual-household systems.

Most soils have capacity to retain large amounts of phosphorous compounds but the absolute quantities and forms present in the sludge and the amounts retained by the soil will require additional study. No problem is anticipated in this area at this time.

Vectors

The project will be operated to minimize any problems due to vectors such as insects or rodents. None of the persons contacted or reporting on sludge use have noted any significant change in population of insects or rodents. However, it is recommended that an ecological survey be conducted in the next phase of engineering studies to inventory present population of disease hosts and all wildlife, and to outline future monitoring, protection or extermination needs.

Esthetic Factors

Inhabitants of the land reclamation site and the adjacent areas will be concerned with the esthetics of the site, particularly with regard to odors and appearance. Sludge storage lagoons may be unsightly or odorous, if undigested sludge is discharged to them. To prevent these problems,

only digested sludge will be utilized in the land reclamation and the application will be in thin layers to avoid odors.

Grading and drainage improvements will reduce erosion throughout the site. Site improvements will include plantings of trees along the boundaries to beautify the area and serve as a visual screen. Because the farms on the site otherwise will not differ in appearance from other farms in the area, the trees are primarily to improve appearance of the site.

Natural Resources

Implementation and operation of the project will not destroy or reduce natural resources, although measures are required to protect the water resources. Other resources although not plentiful consist of some coal and fish and wildlife.

The drainage and runoff control features discussed above will protect the ground and surface-water resources from damage due to increased mineralization, as well as from any health hazard. Increased levels of nitrogen or phosphorous may cause algae-growth problems, so the control features have been recommended in order to assure that the Kankakee River or any adjacent aquifers are protected. Drainage - treatment facilities have been investigated, although it now does not seem likely that they would be required.

The basic concept of the project is the improvement of the soil productivity. Crop production capacity will be improved, to a level nearly equal to that of the most fertile Illinois soils, as a result of the sludge utilization, and associated irrigation, grading and drainage improvements.

Some coal deposits may exist within the project boundaries. However, the fact that they have not been mined, in several decades of mining in the immediate vicinity, suggests that they are not significant economically. Project operations would not prevent future mining, in any event. No other mineral resources are known to exist in this area.

The project operation would probably impair somewhat the fish-life within the area, although it is unlikely that these small streams have significant production now. The cropping and cover proposed for the site should enhance production and hunting of upland-game birds, as discussed in Chapter V. The recommended ecological survey should provide information on background counts of the main species and outline production or protection needs.

Chapter VII

RECOMMENDED ENGINEERING STUDIES AND INVESTIGATIONS

The next stage of project implementation should include engineering studies to design and construct the project. The studies should be divided into two stages; (a) a design report investigation for the functional design and establishment of design criteria and (b) a contract document phase for final design, cost estimation and project construction.

Both stages will be required for the Phase 3 (Essex Site). Since contract documents for the Phase 2 (Tinley Park Site) will be required in about six months, the functional design studies for that site will be quite limited, drawing primarily on the information developed for this report.

Design Report

The design report should comprise (a) a summation of the design criteria required for the final design which would be undertaken in the contract document phase and, (b) an accurate estimate of construction cost in sufficient detail for use in project financing. The criteria should include, but not be limited to, the considerations outlined in Table VII-1. These investigations can be loosely grouped in the headings (a) sludge properties, (b) conveyance system, (c) agricultural development, and (d) farm management.

Sludge Properties.

This investigation has revealed that there is a deficiency in the available data to define adequately the physical and chemical properties of digested sludge. These data can be obtained by laboratory analysis and testing, by field testing and by further research into published records.

TABLE VII-1

OUTLINE OF WORK FOR FUNCTIONAL DESIGN AND
PREPARATION OF DESIGN MEMOS

Study Phase		Assignments		
		MSD	U of I	Consultant
A.	Sludge Properties:			
1.	Laboratory analysis	(X)	(X)	X
2.	Research plots		X	
3.	Hydraulic testing	(X)		X
4.	Detailed study of sludge production	(X)		X
5.	Process modification possibilities	X	(X)	(X)
B.	Conveyance System:			
1.	Field surveys, drilling			X
2.	Selection of materials	(X)		X
3.	M & O considerations	(X)		X
4.	Hydraulic analysis			
a.	Optimum concentration techniques, effect on conveyance	(X)		X
b.	Friction factor	(X)		X
c.	Transients			X
5.	Lagoon sale evaluation	(X)		X
6.	Pumping stations			X
7.	Cost estimates			X
8.	Economic analysis			X

Study Phase	Assignments		
	MSD	U of I	Consultant
C. Agricultural Development:			
1. Photogrammetry			X
2. Soil sampling, mapping			X
3. Drainage surveys, drilling, design			X
4. Reservoir surveys, drilling, design			X
5. Groundwater surveys, drilling, design			X
6. Initiate monitoring system	(X)		X
7. Water-supply sources			X
8. Sludge & irrigation system design			X
9. Develop conservation plan		(X)	X
10. Cropping plan		(X)	X
11. Domestic water system			X
12. Cost estimating			X
13. Economic analysis			X
D. Farm Management:			
1. Develop operating organization	(X)	(X)	X
a. Sludge & water delivery			X
b. Farm operations			X
2. Management criteria; rules			X
E. Report			X

X denotes basic responsibility
(X) denotes supporting contributions

It is particularly important to establish the level and statistical variation of such chemical constituents as nitrogen, phosphorus, zinc, chromium, boron, and molybdenum. Sludge viscosity and dewatering characteristics are also essential, as are evaluations of possible process modifications to provide lower nitrogen levels or to increase concentrations of suspended solids in the sludge.

Conveyance System.

The Sanitary District tentatively selected a pipeline as the method of transport. However, transport by rail, although more expensive than a pipeline, may prove more desirable because existing rail lines can provide access to many sites.

It is inherent in the schemes involving rail or barge transport that the sludge be concentrated to minimize hauling costs. In addition, figures developed for this report indicate that it may be more economical to concentrate sludge for pipeline transmission (See Appendix A). Therefore, it is recommended that further investigations be made to determine the feasible methods and costs of concentration, including concentration by settling, centrifugation or vacuum filtration.

An analysis of pumping costs, construction costs and concentration costs should be prepared to determine the most economical pipe diameter or numbers of railcars or barges required. Piping will be required in all schemes and, therefore, a study should be made to determine the best suited of the various pipe materials available. Hydrogen sulfide gas, grit, grease, and hydrostatic pressure must be considered in the selection of material.

Insufficient data are available to accurately determine friction losses, and an accurate value should be determined by a large scale test. This test

also would provide information about minimum allowable velocities to avoid deposition, optimum concentrations of sludge, the required cleaning interval, and the degree of friction factor recovery attributable to cleaning.

A preliminary analysis of surge effects was performed for this study. It indicates that additional studies of the magnitude of pressure changes should be performed, to determine the need for design features, such as surge suppressors or slowclosing valves, to prevent pipeline or pump damage.

Agricultural Development.

The design criteria to be established in the area of agricultural development are largely without precedent. Data will be available from the research efforts by the University of Illinois which are described in Annex 1.

Some information also has been developed during the studies for this report.

Photogrammetry and map preparation will be required for accurate layout and preliminary design. Field drilling and exploration will be required to provide data for design of drainage, reservoir and groundwater protection features and to determine storage requirements to prevent stream pollution. An ecological survey should be conducted to provide information on current population and species of rodents, insects, and wildlife.

Basic hydrologic and design studies will be necessary for the irrigation-supply source and system. Designs of cropping and sludge application systems and of the water supply system will be needed. Cost estimates will be required together with economic analysis to determine the optimum development plans.

Farm Management .

Farm management alternatives must be examined to develop the management organization and procedures best suited to this project. Further, the possible management policies need to be further examined, particularly in the area of the division of farm income between the Sanitary District and the farm lessees.

Contract Documents

The final phase of engineering would comprise the completion of detailed designs, preparation of construction drawings, specifications and other contract documents. The areas of study would generally parallel the outline of functional design studies, Table VII-1. These can be defined for the Tinley Park (Phase 2) Site at present, but this phase of engineering can be specified reliably for the Phase 3 site only after completion of the functional design report and appraisal of early results from the University of Illinois research.

Estimated Cost

Based on the definition of work and time-table outlined above, the estimated cost of engineering, economic, farm management and other investigations are as follows:

Functional Design (Phase 3)

Engineering Costs		\$478,000
Direct Costs:		
Laboratory analyses, tests	25,000	
Photogrammetry	45,000	
Test Drilling	54,000	
Travel and other	<u>31,000</u>	
Sub-total		<u>155,000</u>
Total, Functional Design Phase 3		\$ 633,000

Contract Documents (Phase 2)

Engineering Costs	\$ 110,000
-------------------	------------

Direct Costs:

Photogrammetry	6,100
----------------	-------

Test Drilling	3,500
---------------	-------

Travel and Other	16,400
------------------	--------

Subtotal	<u>26,000</u>
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Total, Contract Documents, Phase 2	\$ 136,000
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Annex to Chapter VII

Research Program of University of Illinois

The University of Illinois has been given a grant by the Public Health Service to study the effects of solid-waste disposal using Sanitary District sludge. The objectives of the study as stated in the application for the grant are:

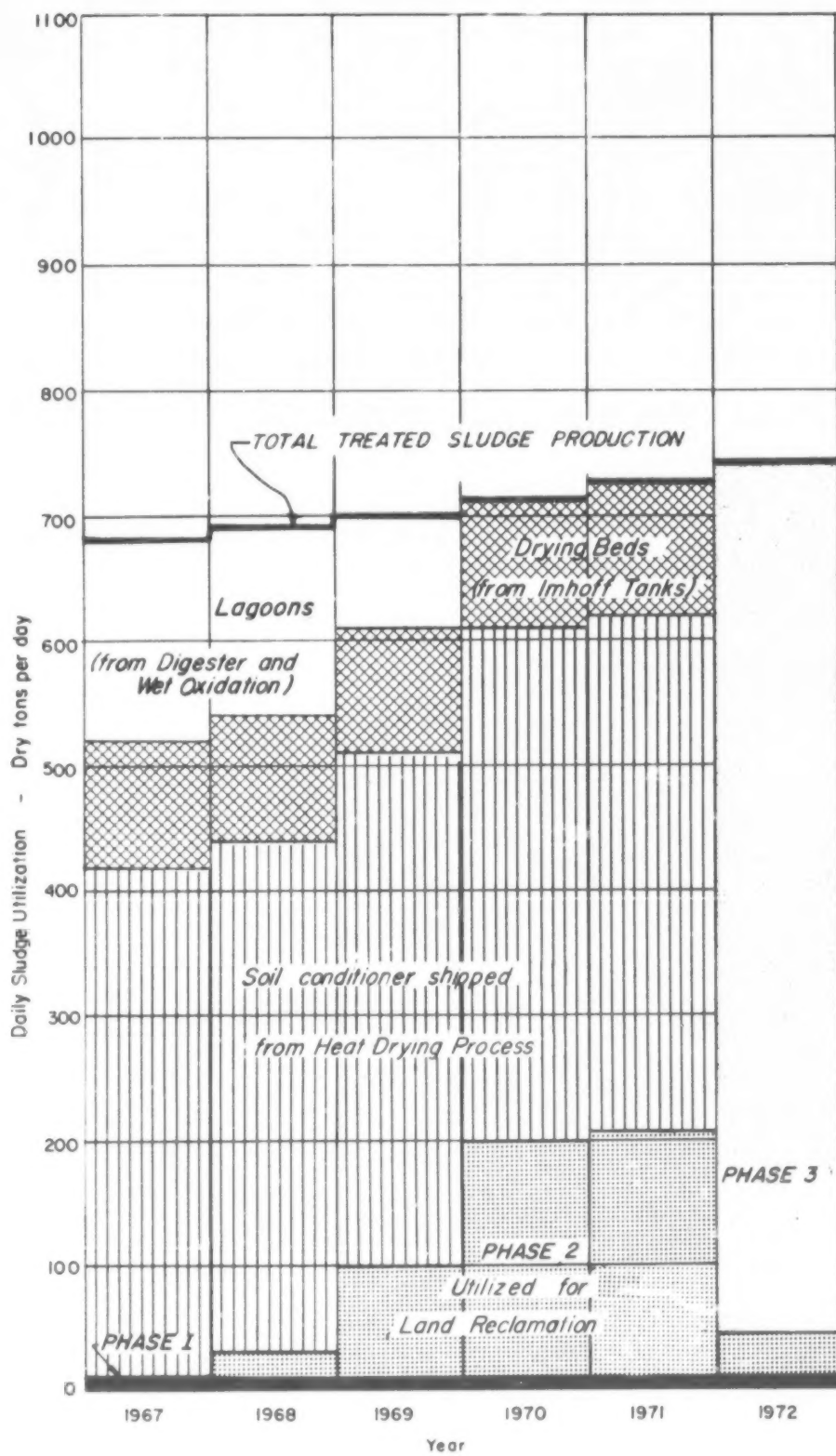
1. To investigate factors relevant to the contamination of surface water and groundwater when large amounts of digested sludge are frequently applied on a sandy soil.
 - a. The number of viable pathogens in digested sludge and their longevity in soils under various environmental conditions will be investigated.
 - b. The rate and distance of movement of pathogenic organisms with water in soils will be investigated.
 - c. The rate of nitrogen mineralization and conversion to nitrate nitrogen in soil under various rates of digested sludge application at various time intervals will be determined. Environmental conditions will be simultaneously monitored. Information with regard to amounts of nitrate nitrogen accumulation and movement with water in soils will be obtained.
 - d. The increase in soluble phosphorus in soils with repeated applications of digested sludge will be evaluated. Phosphorus build-up in soils will be investigated to determine to what if any extent it may eventually enter water supplies in abnormally high concentrations.

2. To investigate factors relevant to the pollution of soils with heavy metals, high soluble salt concentrations, grease and organic compounds, an molecular ions.
 - a. The concentrating of heavy metals in soils as a result of frequent application of digested sludge will be investigated. Soil characteristics such as oxidation-reduction status, organic matter, and pH will be varied to see how heavy metal absorption by plants varies. The affect of heavy metal absorption of the growth of various plants will be investigated.
 - b. The deposition of dissolved salts in the soil profile when various leaching conditions follow the frequent application of large amounts of digested sludge will be investigated. Methods of using plants to extract large quantities of soluble salts will be explored.
3. To investigate, under field conditions, factors relevant to the method, frequency rate, and time for safely applying digested sludge on land.
 - a. Although information gained from objectives one and two above will determine to some extent the method, frequency, rate and time for digested sludge applications, there will no doubt be some latitude of choice that will need to be resolved by field testing. Cost, ease of handling and manipulation, the convenience afforded by soil and weather conditions, the protection of water supplies from contamination by excessive runoff water, etc., will be investigated in the field.
 - b. Because growing plants will paly a vital part in the illimitable use of a particular land area for digested sludge disposal, some screening of plants will be necessary. Plant species will be selected according to their usefulness in absorbing elements of various kinds and to their adaptability to flooding and temporaty oxygen deficiencies in the root zone. The plants selected will not be tested with regard to their value as forage or grain for animal consumption, but will be species locally recognized as such.

- c. The need for supplemental fertilization to enhance the absorption of specific elements supplied by the digested sludge will be investigated.
- d. Plant residues left on the land from the preceding crop will alter infiltration rates of the water applied by digested sludge applications. Plant residues will affect decomposition rates of the organic materials, the fate of some of the nitrogen, and the reactions of other elements supplied by the digested sludge. The presence of plant residues will be one of the environmental variables evaluated in objective 1 and 2 above. Results of laboratory studies of residues will be compared to results of field studies of residues.

EXHIBITS

1. Sludge Utilization Schedule
2. Development Program for Sludge Utilization Sites
3. Layout of Phase 1 Test Plots
4. Alternative Phase 2 Sites
5. Detail Location Map, Tinley Park (Phase 2) Site
6. Alternative Phase 3 Sites
7. Recommended Pipeline Alignment
8. Present Land Use Sandy-Soils Area
9. Bedrock Geology and Overburden Thickness
10. Essex Site Development Plan



LEGEND

	Phase 1	Land	Reclamation	Development
	Phase 2	"	"	"
	Phase 3	"	"	"

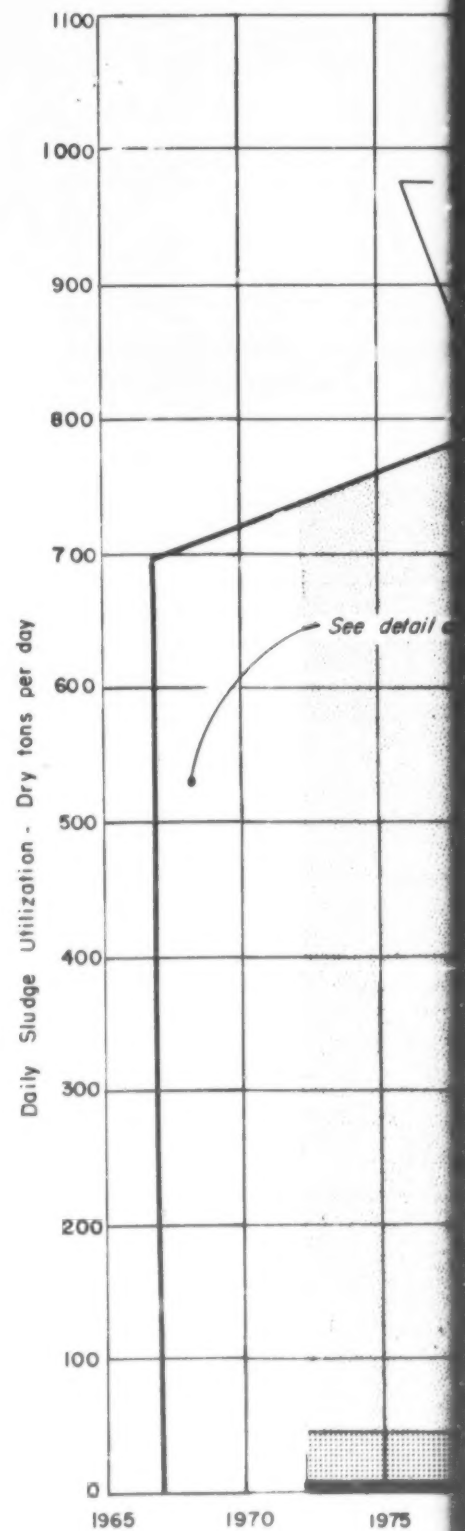
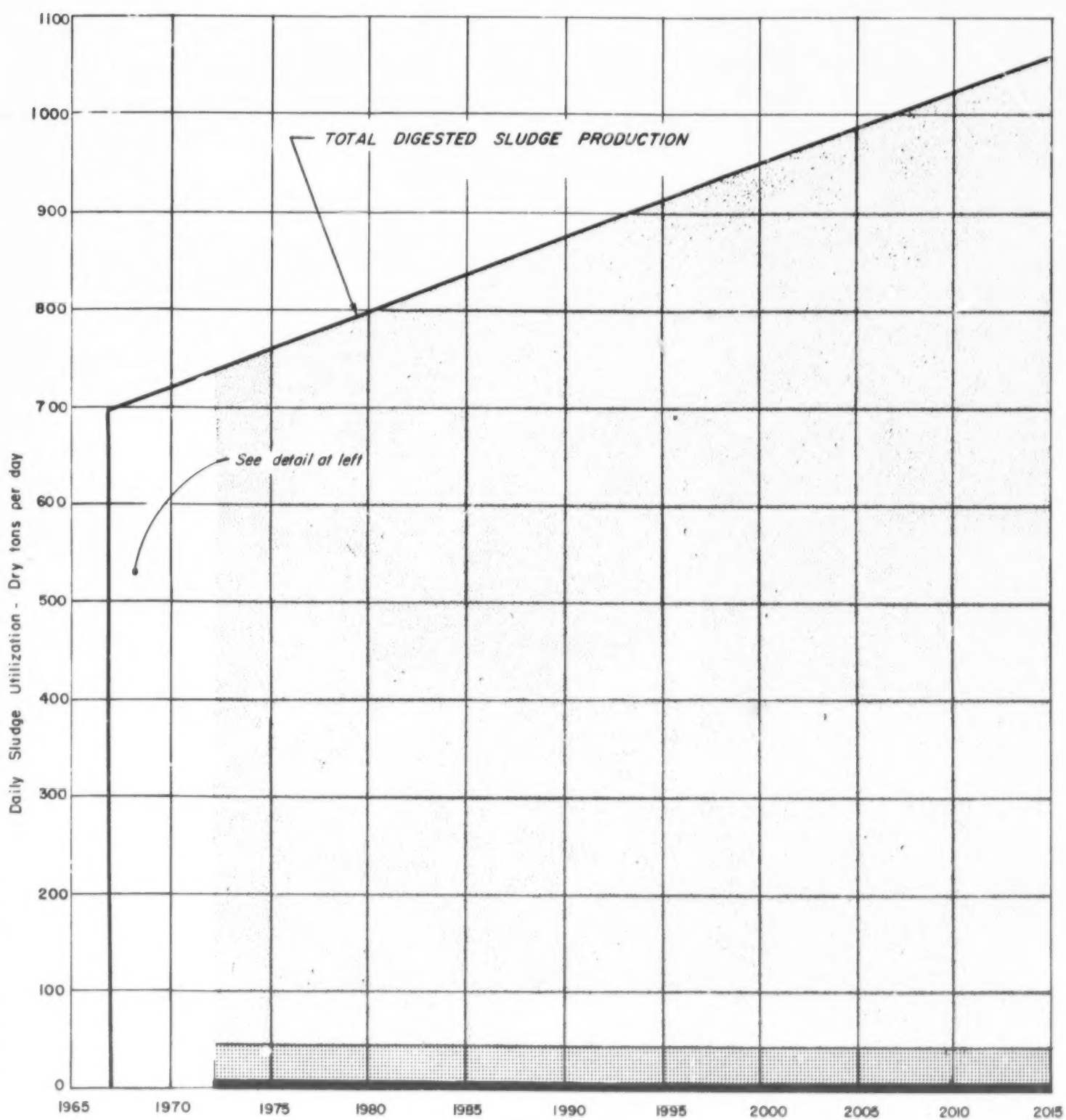


EXHIBIT I



LAND RECLAMATION PROJECT SLUDGE UTILIZATION SCHEDULE

DESCRIPTION			1967	1968	1969	1970
PHASE 1	W-SW Plant Plot	Acres 10				
	Apply Sludge					
PHASE 2	-Cook County Site					
	Land Purchase					
	Design Studies					
	Grading and Construction					
	Apply Sludge 1st Block	105				
	2nd Block	315				
	3rd Block	580				
	4th Block	720				
PHASE 2 C	-Cooperative Sites					
PHASE 3	-Ultimate Project					
	Exploration and Design					
	Land Purchase					
	Site Preparation and Construction					
	Apply Sludge					

LEGEND

--- Engineering, Land Acquisition
& Construction

■ High-rate sludge loading

— Standard-rate sludge loading

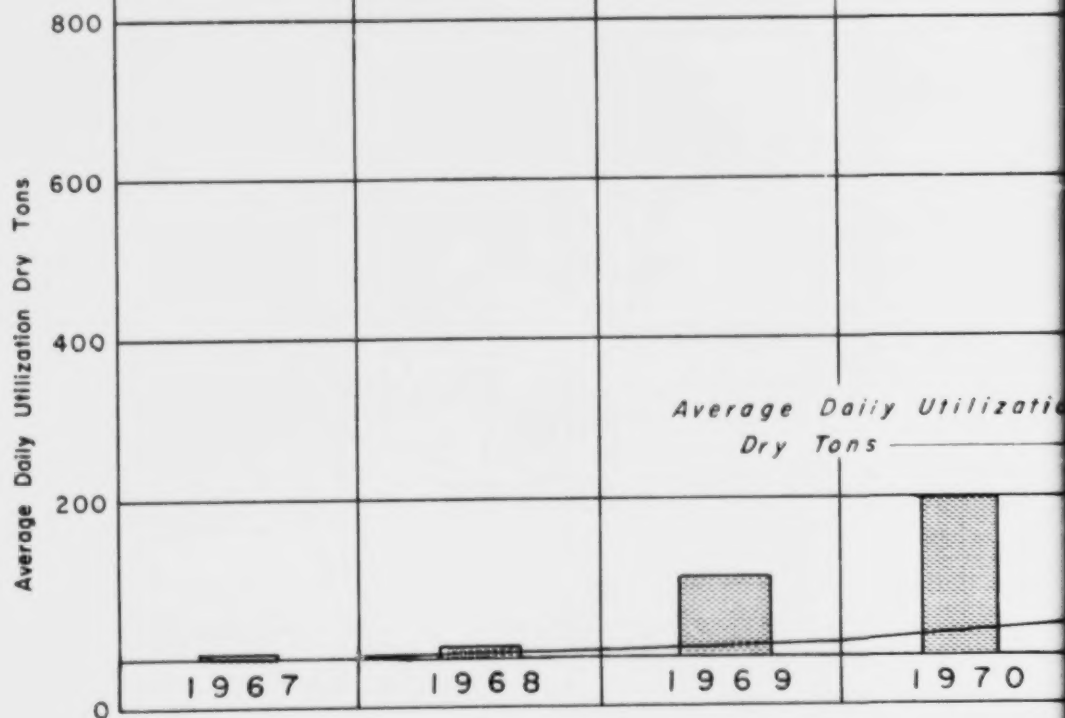
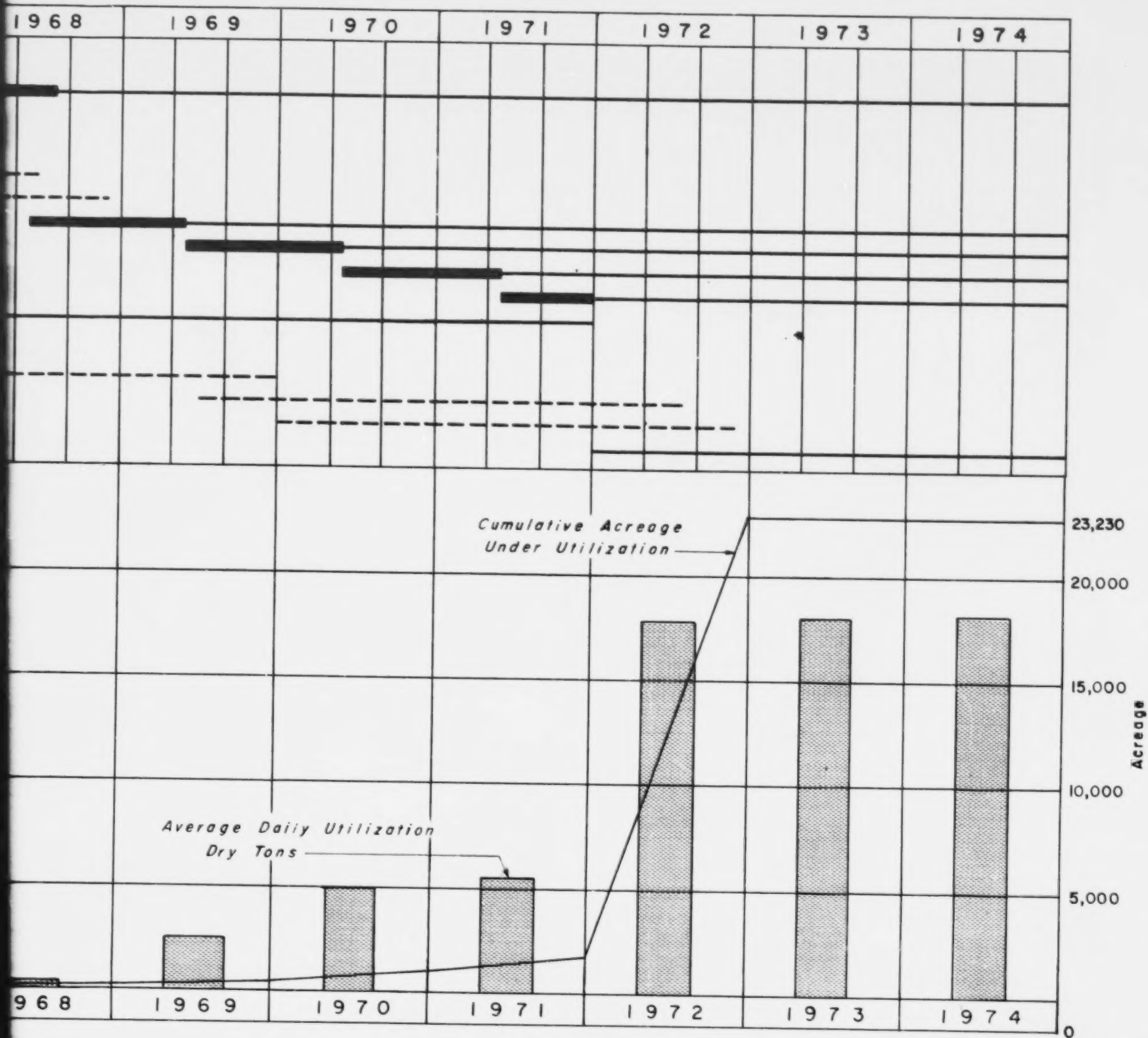


EXHIBIT 2



LAND RECLAMATION PROJECT
DEVELOPMENT PROGRAM
FOR SLUDGE UTILIZATION SITES

B

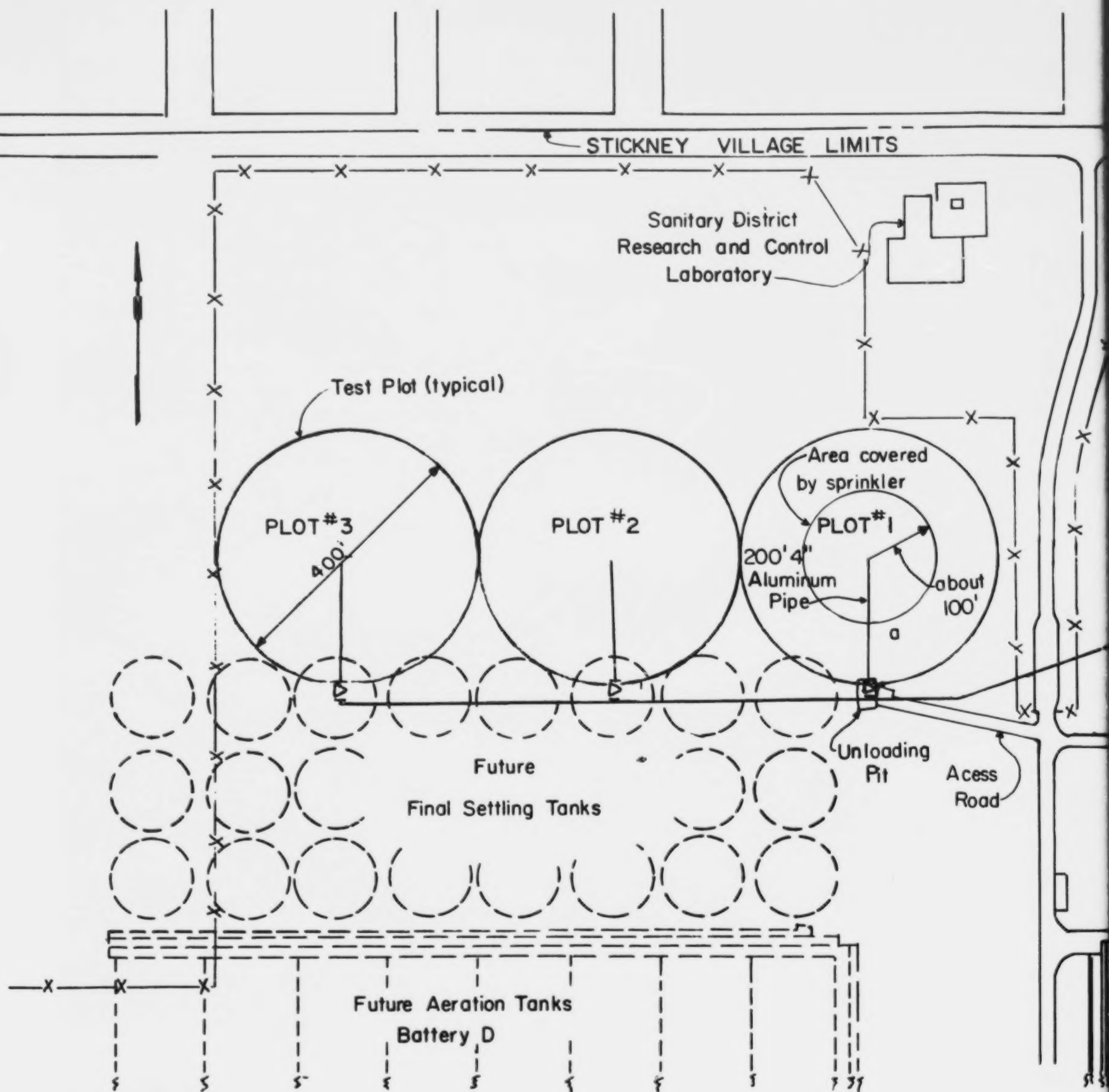
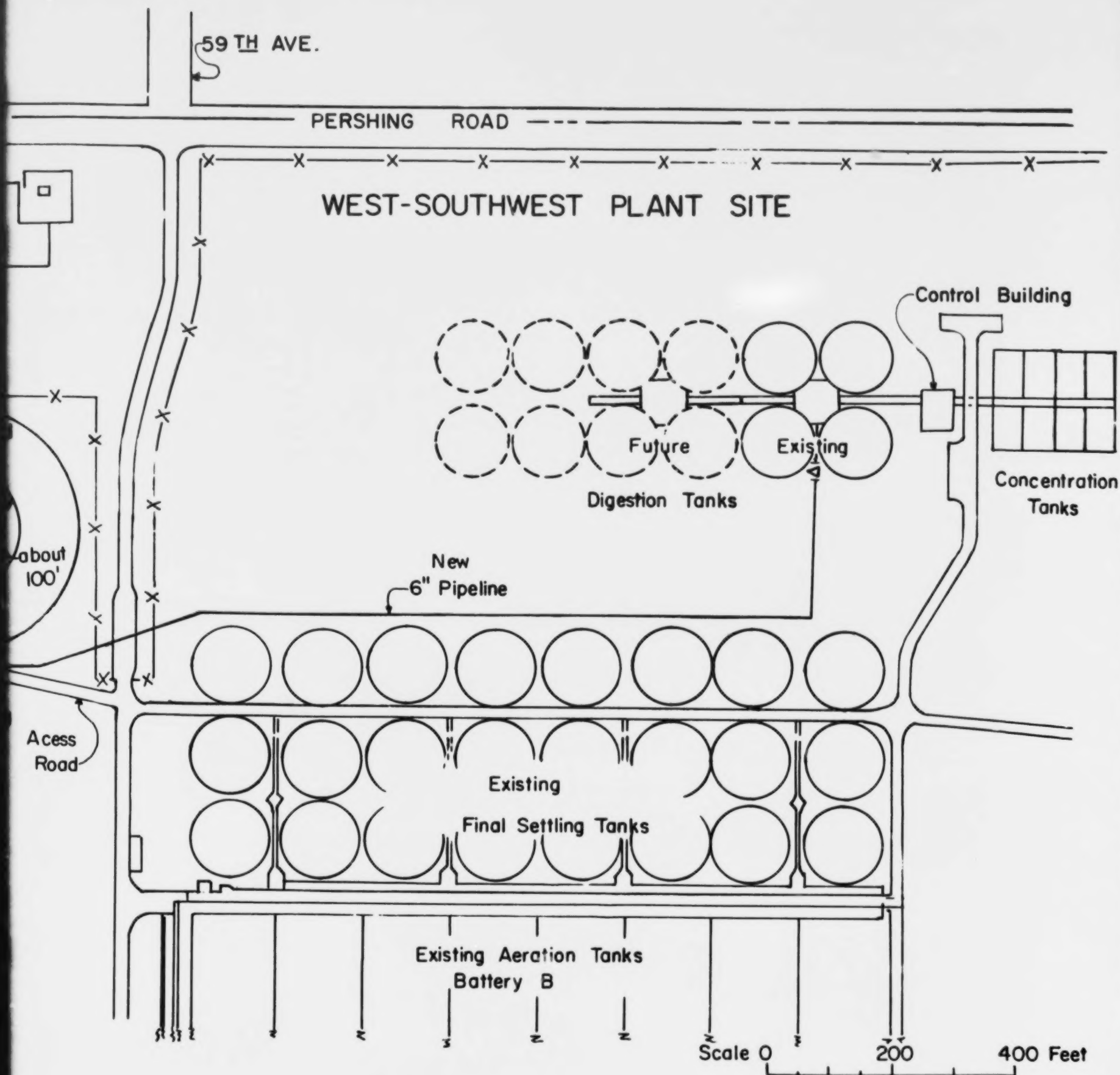
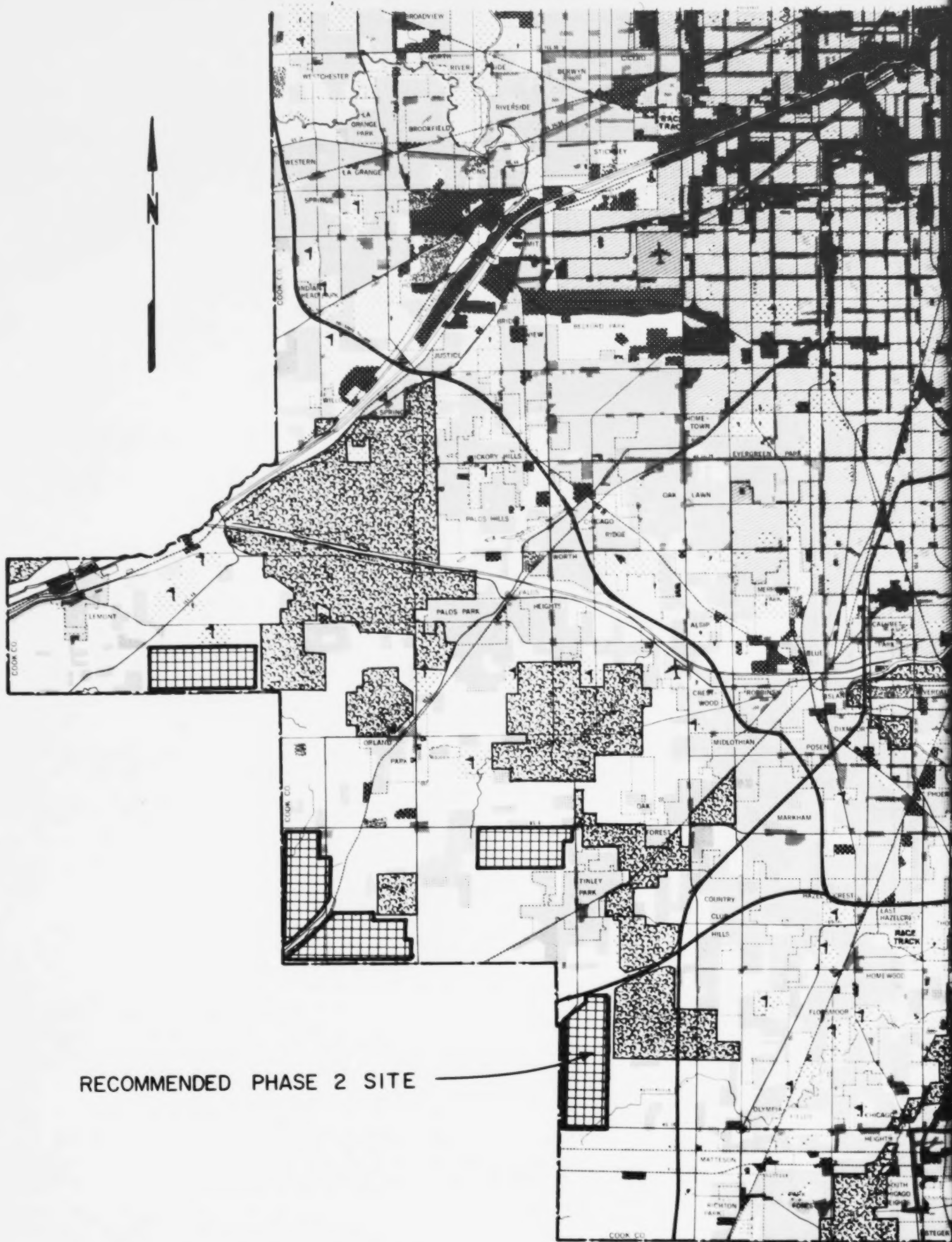


EXHIBIT 3



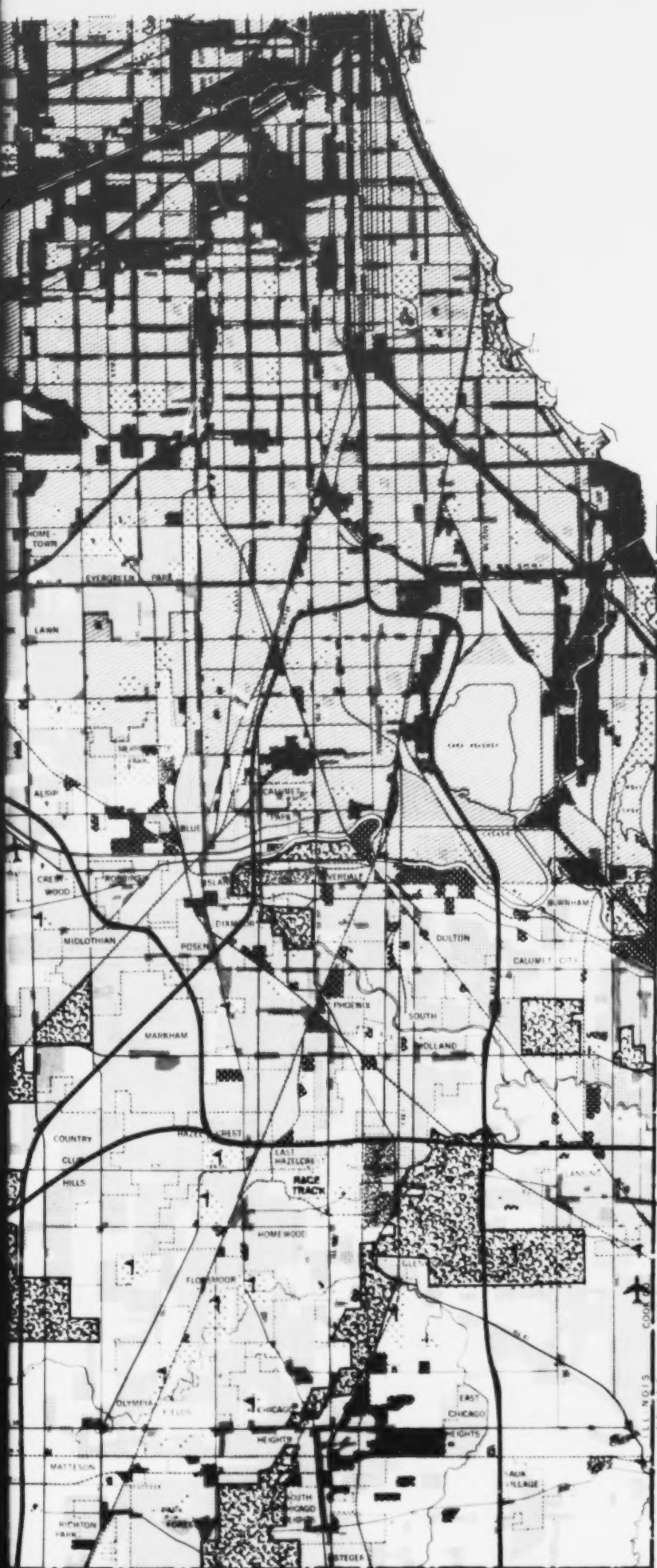
LAND RECLAMATION PROJECT
 LAYOUT OF PHASE I
 TEST PLOTS

B



RECOMMENDED PHASE 2 SITE

A



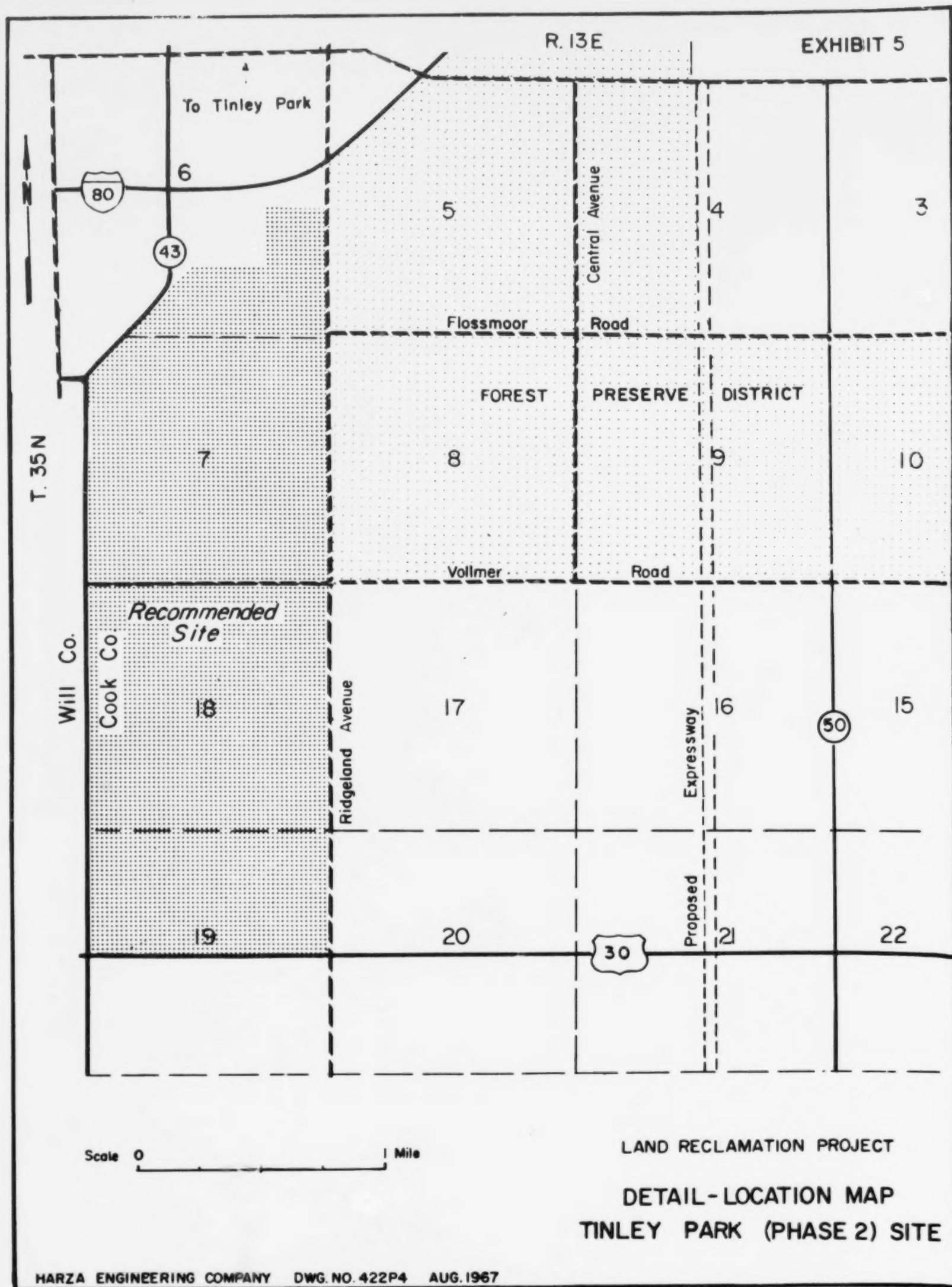
LEGEND

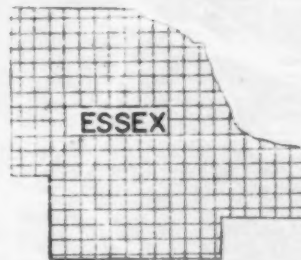
-  Alternative Phase 2 Sites
-  City of Chicago
-  Residential
-  Commercial
-  Industrial
-  Public Buildings
-  Airports
-  Higher Education
-  Public Open Space
-  Golf Courses
-  Cemeteries
-  Outdoor Amusement
-  Agriculture / Vacant
-  Mines



LAND RECLAMATION PROJECT
 ALTERNATIVE PHASE 2 SITES
 SOUTH COOK COUNTY

B





LEGEND:



Alternative Sites

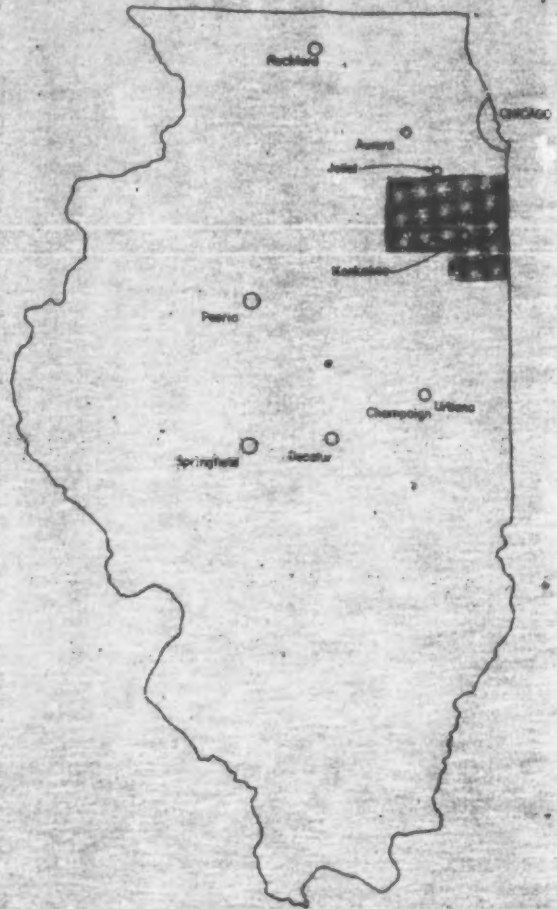


City or Town



Strip Mine

EXHIBIT 6



KEY-MAP

LEGEND

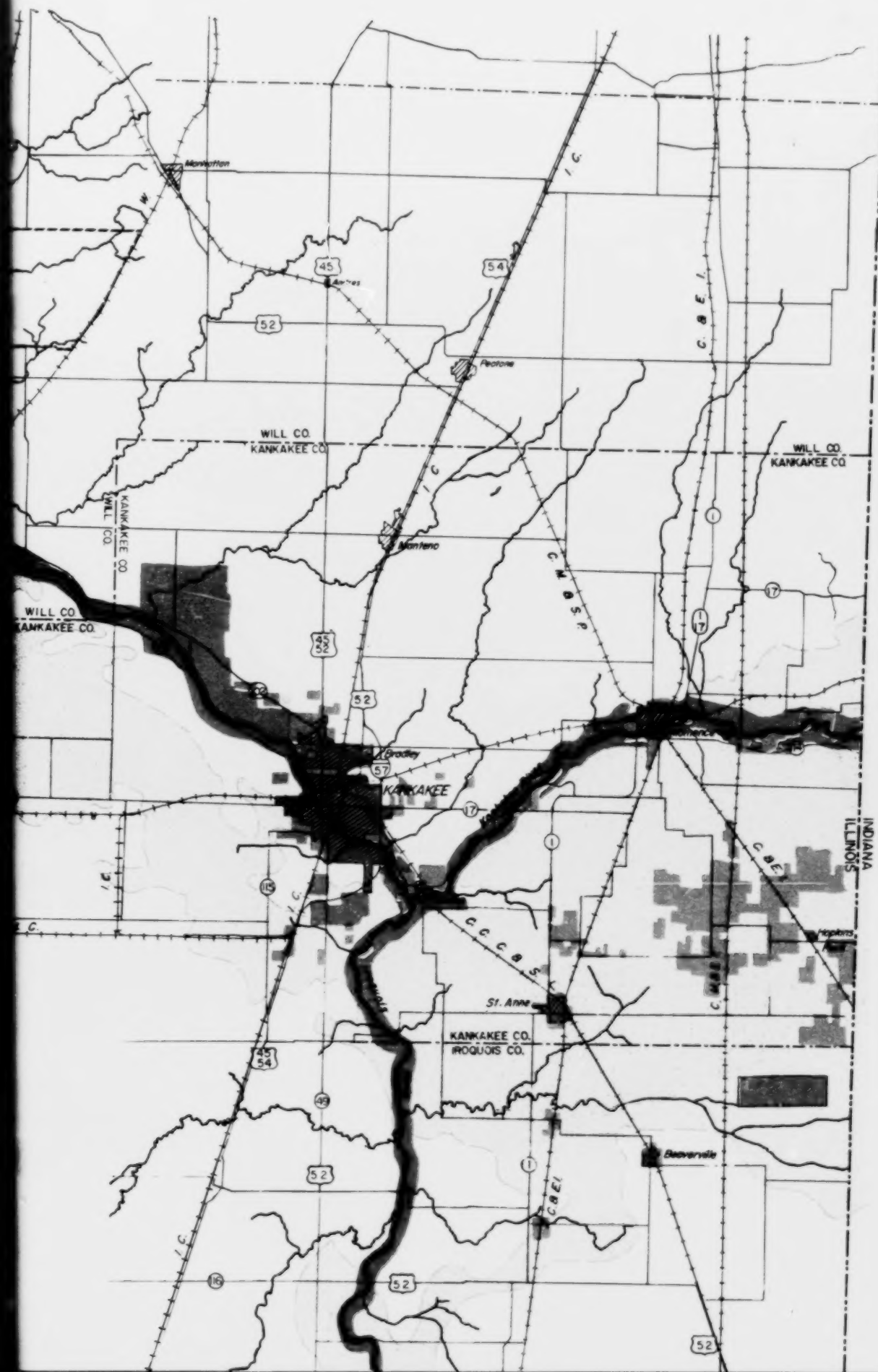
- Proposed Project
- Existing Project
- Water
- Highway
- Railroad
- County Line
- City Line

LAND RECLAMATION PROJECT

ALTERNATIVE PHASE 3 SITES



A



LEGEND:

- Sandy soil area
- Densely populated area
- Recreational area
- Mine spoil area

Scale 0 1 2 3 4 Miles

LAND RECLAMATION PROJECT
PRESENT LAND USE
SANDY-SOILS AREA

B





NOTE:

After State Soil Survey Series map
 Lithology, Contour, Profile, or other data
 U.S. Mineral or Geological Survey of 1900
 1917

EXPLANATION:

- 25' Contour Interval, 100' Contour Interval
- 100' Contour Interval
- 100' Contour Interval

GEOLOGIC LEGEND:

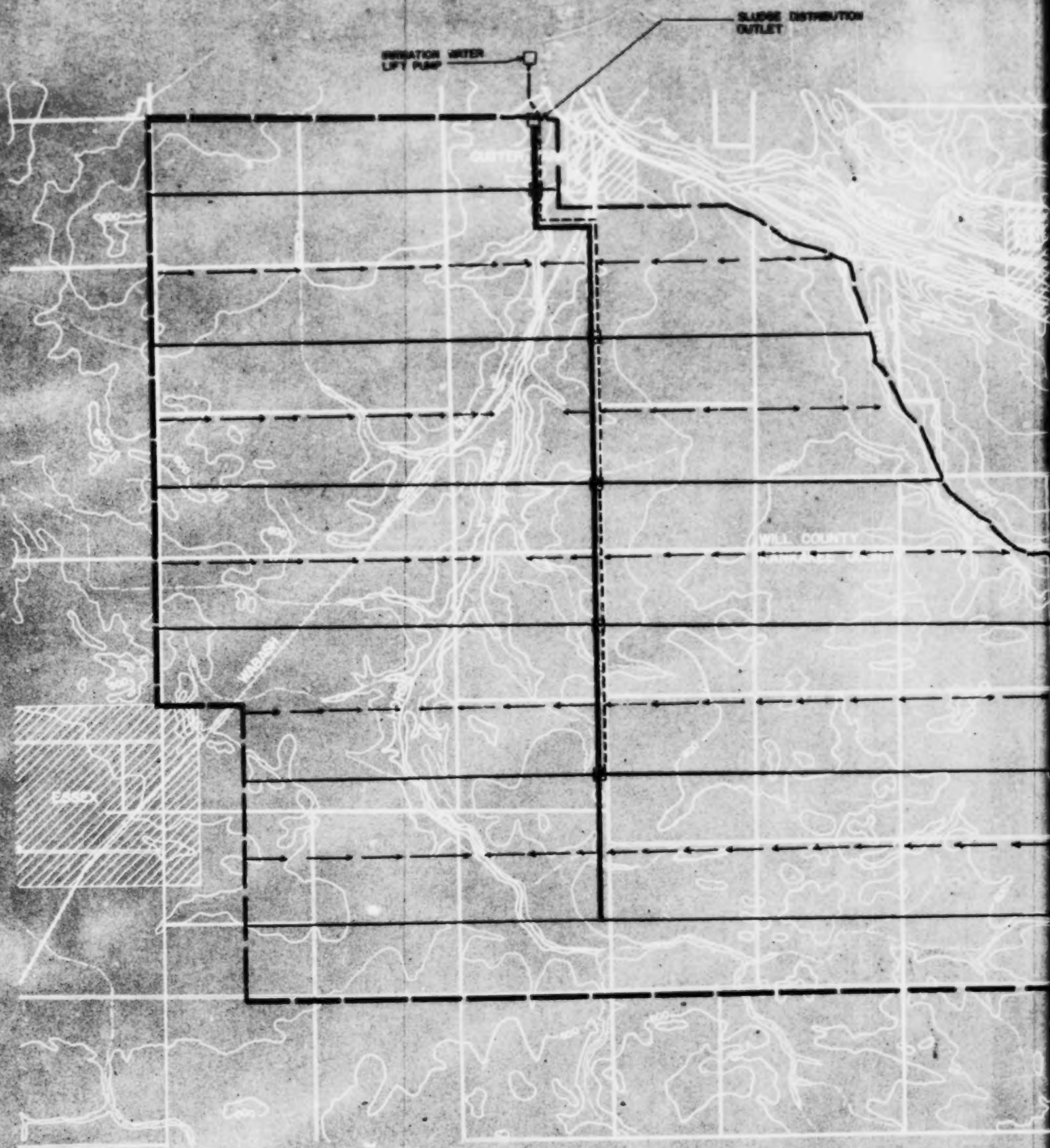
- P PENNSYLVANIAN - Carboniferous
- D DEVONIAN - Devonian
- S SILURIAN
- O ORDOVICIAN - Ordovician
- G GEOLOGIC - Geological

LEGEND:

- S Sandy soil area
- D Densely populated area
- R Recreational area
- M Miscellaneous area

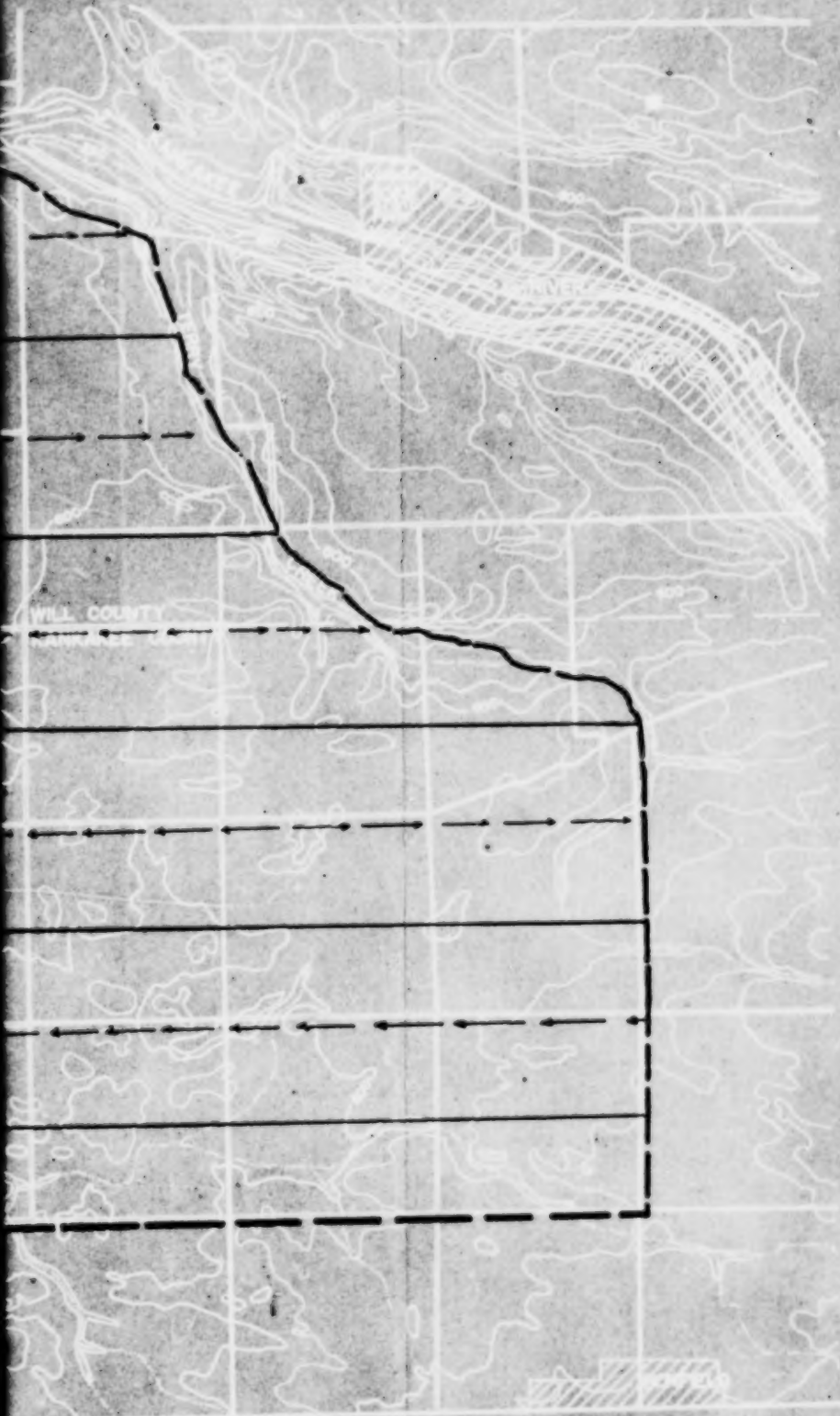
Scale 0 1 2 3 4 Miles

LAND RECLAMATION PROJECT
GEORGE C. BROWN
AND OVERSIGHT, THOMAS



1A

SLUDGE DISTRIBUTION
OUTLET



LEGEND

- PROJECT BOUNDARY
- LATERALS
- SLUDGE PIPELINE
- - - DRAINAGE DITCHES
- - - OPEN CANAL
- BOOSTER PUMP

Scale 0 2000 4000 Feet

LAND RECLAMATION PROJECT
ESSEX SITE
DEVELOPMENT PLAN

B

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Appendix A

SLUDGE PROPERTIES

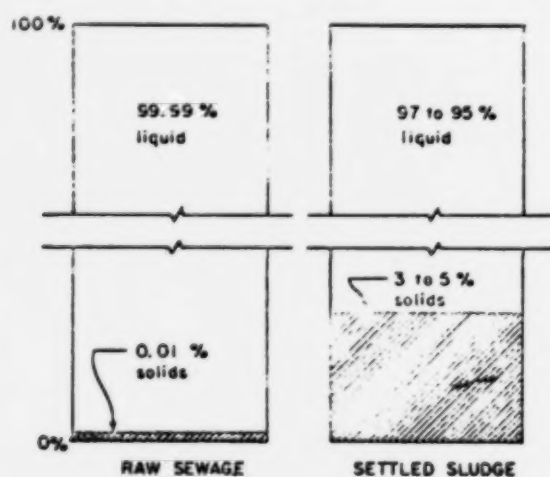
Sludge treatment and disposal is the greatest problem in sewage and industrial waste treatment processing. Concentration, stabilization and disposal of sludge are so expensive, because of the land, equipment and number of operations required, that sludge treatment and disposal frequently costs as much as the combination of all other sewage treatment processes.

The term "sludge" is defined here as the concentration of solid materials withdrawn from the total waste stream of domestic and industrial waste water. Untreated sewage sludge is a concentration of organic and inorganic solids, removed from the combination of domestic and industrial wastes, which becomes malodorous if left untreated. This project is concerned with the utilization of processed (digested) sludge which has been stabilized. After adequate treatment, the sludge loses its objectionable odor and assumes the properties of a plant fertilizer and soil conditioner. To appreciate this conversion of a nuisance to an asset, a review of the sludge collection and treatment process is essential.

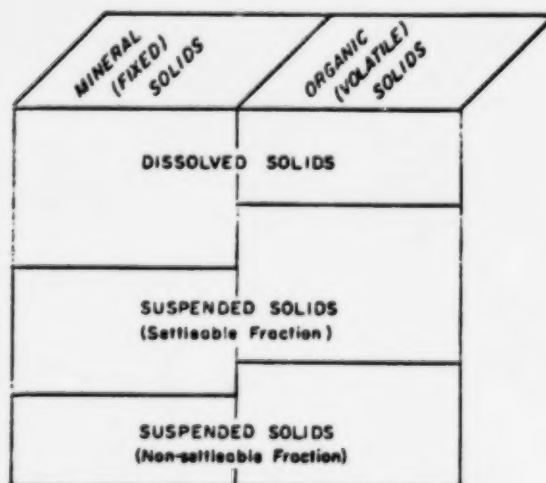
Sludge Collection and Treatment

Domestic sewage containing industrial wastes normally has a suspended solids concentration of about 0.02 to 0.03 percent. The solids include human wastes, garbage, sand, grease and other particulate matter.

A flow diagram of the treatment processes in use at the Sanitary District Plants is shown on Exhibit A-1. The sewage passes through preliminary settling tanks, Exhibit A-1, in the treatment plant, and solids settle out of the sewage stream. The relative volumes of solids present in sewage and sludge are shown in part A of Fig. A-1.



A. SOLIDS CONCENTRATION IN SEWAGE AND SETTLED SLUDGE



B. SOLIDS CLASSIFICATIONS

FIGURE A-1 SOLIDS CONCENTRATION AND CLASSIFICATIONS IN SEWAGE AND SLUDGE

The settled sludge is withdrawn from settling tanks with solids concentrations of 4 to 5 percent. Bacteria, protozoa and viruses abound in this raw, settled, sludge, and the use of raw sludge would create a definite public health hazard.

The sludge may be treated in several ways after it is withdrawn from sedimentation tanks. At the Sanitary District's activated sludge plants, it is combined with incoming sewage and aerated, forming clumps of organic matter called activated sludge floc. Protozoa and bacteria, present in these flocs, decompose organic matter and convert dissolved nutrients in the sludge into cell matter. Activated sludge flocs are then removed in the final settling tanks, as sludge and pumped into heated digesters.

The settled, untreated sludge is composed of several classes of solid matter. The solids are classed in analyses as fixed (mineral) solids or volatile (organic) solids. In addition, solids are also described as dissolved or suspended, with the suspended solids further grouped into settleable and suspended classes. This solids nomenclature is shown as part B in Figure A-1. The total sludge volume produced from sewage is estimated by measuring the concentration of suspended solids and the volume of flow. It was assumed in this study that 90 percent of the suspended solids will be removed from the sewage as untreated sludge.

Presently the weight and volume of untreated sludge are reduced by both heated and unheated digestion, the wet air oxidation process, or vacuum filters and heat drying. The Sanitary District proposes to use digesters for future operations.

Heated digesters (95 degrees, F) operate at the Calumet and West-Southwest Plants. Bacteria act on the settled, untreated, activated sludge to convert about 30 percent of the organic matter to gas. The digestion process requires about two weeks and produces a stablized sludge which has a slight odor, similar to moist earth. The viruses and bacteria largely have been destroyed or combined in stable complexes. The digested activated sludge contains much water in the form of bacterial cells, which makes it difficult to dewater and concentrate.

At the West Side Plant, Exhibit A-1, untreated sludge is also collected in unheated (Imhoff) settling and digestion tanks. Because this organic matter in the sludge is not converted into cell matter, as in the activated sludge process, the characteristics of Imhoff digested sludge differ from digested activated sludge. Digested Imhoff tank sludge loses water faster, and contains less volatile matter than digested activated sludge. Digestion using Imhoff tanks is inefficient compared to heated digestion because the process efficiency depends on outside air temperatures and has no provisions for mixing the tank contents. The time for Imhoff tank digestion varies from one to three months. It is anticiapted in this report that in year 2015 sludge will be treated by only Imhoff tanks and heated digesters. The digestion processes result in volatile solids reductions which are summarized in Table A-1, based on Sanitary District operating records ^{1/}. The process labeled "Composite" indicates a value proportioned to process quantities assumed in year 2015.

^{1/} Annual Reports of Maintenance and Operation Department, 1964, 1965, 1966. Metropolitan Sanitary District of Greater Chicago.

Table A-1

VOLATILE SOLIDS REDUCTION

Process	Reduction of Volatile Solids , %	
Imhoff Tank Digestion	50	50
Heated Digester Digestion	30	30
Wet Air Oxidation	55	-
Composite	37	33

For the land reclamation project, it was assumed that sewage entering the digesters contains approximately 75 percent volatile matter. Digestion reduces the weight of volatile solids by 30 percent, leaving digested sludge containing about 50 percent volatile solids. A graph showing the forecasted increase in digested sludge production is shown as Exhibit A-2. It was assumed for this report that Imhoff digestion produces a 40 percent reduction of total solids entering the Imhoff tank and heated digestion produces a reduction of 22 percent.

Physical PropertiesGeneral Characteristics

Digested sludge is a suspension containing 3 to 10 percent solids, with about 2,500 parts per million (ppm) of total dissolved minerals.

One cubic foot of wet sludge weighs about 63 pounds with 3.5 percent solids concentration. As water in the sludge evaporates or is withdrawn by centrifuging, decanting or filtering, the solids concentration increases and the volume may decrease to one-half or one-quarter of the original volume with a density of 20 to 30 pounds per cubic foot. This dewatering characteristic differs with origin of the sludge, as indicated above. As an example, digested sludge from Imhoff Tank digesters often requires about 30 days to concentrate to 75 percent moisture on sand drying beds. Digested activated sludge requires about 60 days, or more, to achieve the same concentration.

Odor Potential

Sludge is considered to be fully stabilized when 75 percent of the volatile solids are destroyed ^{1/}. However, because it takes too long to achieve this reduction, most digesters are designed for 50 to 60 percent volatile solids reduction. Since the Sanitary District digesters may provide only about 33 percent reduction, some additional decomposition is expected after sludge is withdrawn from the digesters. Whether this decomposition produces objectionable odors depends on several factors. The objectionable odor generally associated with sewage is from hydrogen sulfide gas, which is produced in several ways. The gas may be produced by bacterial reduction of sulfates or

^{1/} "Sewage Treatment Plant Design," Water Pollution Control Federation, Manual of Practice No. 8, 1963.

by reactions between bacterially produced enzymes and amino acids containing sulfur. There should be no sulfates present in the sludge because sulfates are reduced in the digestion process. However, gas may still be produced by the enzymatic process. In addition, the sulfur contained in the sludge may be oxidized to sulfate and then reduced by soil bacteria forming hydrogen sulfide gas.

Odor problems have not been experienced where sludge was used for agricultural purposes, and odor problems are infrequent where adequately digested sludge has been stored in lagoons. It is impossible to estimate accurately the extent of the gas produced, but it may be generally stated that conditions that inhibit bacterial decomposition rates could be employed to minimize the odor problem. Thus, several thin applications would be preferable to a heavy application. Further evaluation of this problem should be produced by the University of Illinois experiments.

Hydraulic Properties

For solids concentrations less than about five percent, sludge behaves like water, with friction loss primarily dependent on surface roughness. Above a concentration of 6 percent, digested sludge exhibits non-Newtonian flow characteristics with friction loss primarily dependent on viscosity. The viscosity varies with the rate of shear which is inherent to the substance and also is related to the pipeline velocity and pipe diameter. General estimates of hydraulic properties have been made on the basis of current knowledge; however, hydraulic testing is recommended to determine, more exactly, (a) the relationship of friction to concentration of solids, (b) the sedimentation properties and (c) the pipeline cleaning requirements.

Viscous properties of digested sludge have been measured for various concentrations^{1/}. If the shearing stress, S_s is related to the shearing rate, du/dy , by the equation

$$S_s = K \frac{(du)^n}{dy}$$

where

$$K = 0.0113 C^{3.4}$$

and,

$$n = 0.817 - 0.843 \log_{10} C$$

where, C is the percent concentration of solids.

For flow of non-Newtonian fluids in a pipeline the Darcy-Weisbach equation is applicable

$$H_f = f \frac{L}{D} \frac{V^2}{2g}$$

The friction coefficient f is determined from the equation

$$f^{-1/2} = \frac{4.0}{n^{0.75}} \log_{10} N_R^{(1-0.5n)} - \frac{0.4}{n^{1.2}}$$

in which, $N_R = \frac{(\text{Density}) (\text{diameter})^n (\text{velocity})^{2-n}}{K 8^{(n-1)}}$

^{1/} Behn, V. C., Journal of Sanitary Engineering Division, ASCE Volume 88, May, 1962.

For a pipeline velocity of approximately 3.5 ft per sec and 1060 tons per day of dry solids, the effects of varying concentration on the Hazen-Williams coefficient (C_{HW}) and the power to overcome pipeline friction are shown in Table A-2

Table A-2

VARIATION IN POWER REQUIREMENTS WITH CONCENTRATION

C(%)	D(in)	Q(cfs)	C_{HW}	Horsepower/mile
3.5	24	10.5	160	11.5
5.0	20	7.3	160	9.6
6.0	18	6.1	160	8.0
8.3	16	4.4	110	16.0
10.5	14	3.5	100	17.0

Chemical Properties

Since sludge is a concentration of assorted domestic and industrial wastes it contains metals, salts and organic matter in amounts greatly in excess of those present in drinking or irrigation waters. Several analyses of Sanitary District sewage sludge are included as Exhibit A-3.

Concentration of some metals and salts are extremely important to the growth of bacteria and plants and are discussed in detail in the Appendices C and D.

Of particular interest to this study are the concentration and forms of nitrogen, dissolved salts, and heavy metals such as zinc, copper and iron. It is obvious from the chemical analyses that sludge is highly variable in nature. Further investigations should be conducted to determine the ranges and variability in the sludge characteristics and in sludge analysis techniques.

Nitrogen in Sludge

Nitrogen content is reported in chemical analyses of sludge as total nitrogen and as ammonia nitrogen, where the nitrogen in organic compounds is that value indicated by the difference between the total and the ammonia nitrogen value. Nitrogen values for Sanitary District sludges are shown in Table A-3. These values have been obtained from complete chemical analyses shown in Exhibit A-3. Values labeled "Composite" were determined by Sanitary District chemists using sludge from digesters, wet oxidation and Imhoff tanks in proportion to the estimated contributions of these units, if all were to continue in operation, in the year 2015.

These analyses indicate that wet sludge contains about five percent nitrogen relative to the weight of dry solids. However, it is estimated that about three percent of the nitrogen is present in the solids and three percent in the solution. On the same basis, the wet sludge contains about three percent phosphate and 0.5 percent potassium. If all the potassium combined with oxygen the percentage as potash would about 0.6 percent. Thus, compared with a 20-10-10 rated commercial fertilizer (containing 20 percent nitrogen, 10 percent phosphate and 10 percent potash), the liquid sludge would be

Table A - 3

NITROGEN QUANTITIES IN SANITARY DISTRICT SLUDGE

	<u>Total Nitrogen (mg/l)</u>	<u>Ammonia Nitrogen (mg/l)</u>	<u>Organic Nitrogen (mg/l)</u>
Calumet Digesters			
June, 1966	1449	603	846
July, 1966	1512	528	984
July, 1967	1967	790	977
Southwest Plant Digesters			
June, 1966	1538	657	881
July, 1967	1542	608	934
July, 1967	1753	736	1017
Composite Value	1689	571	1118

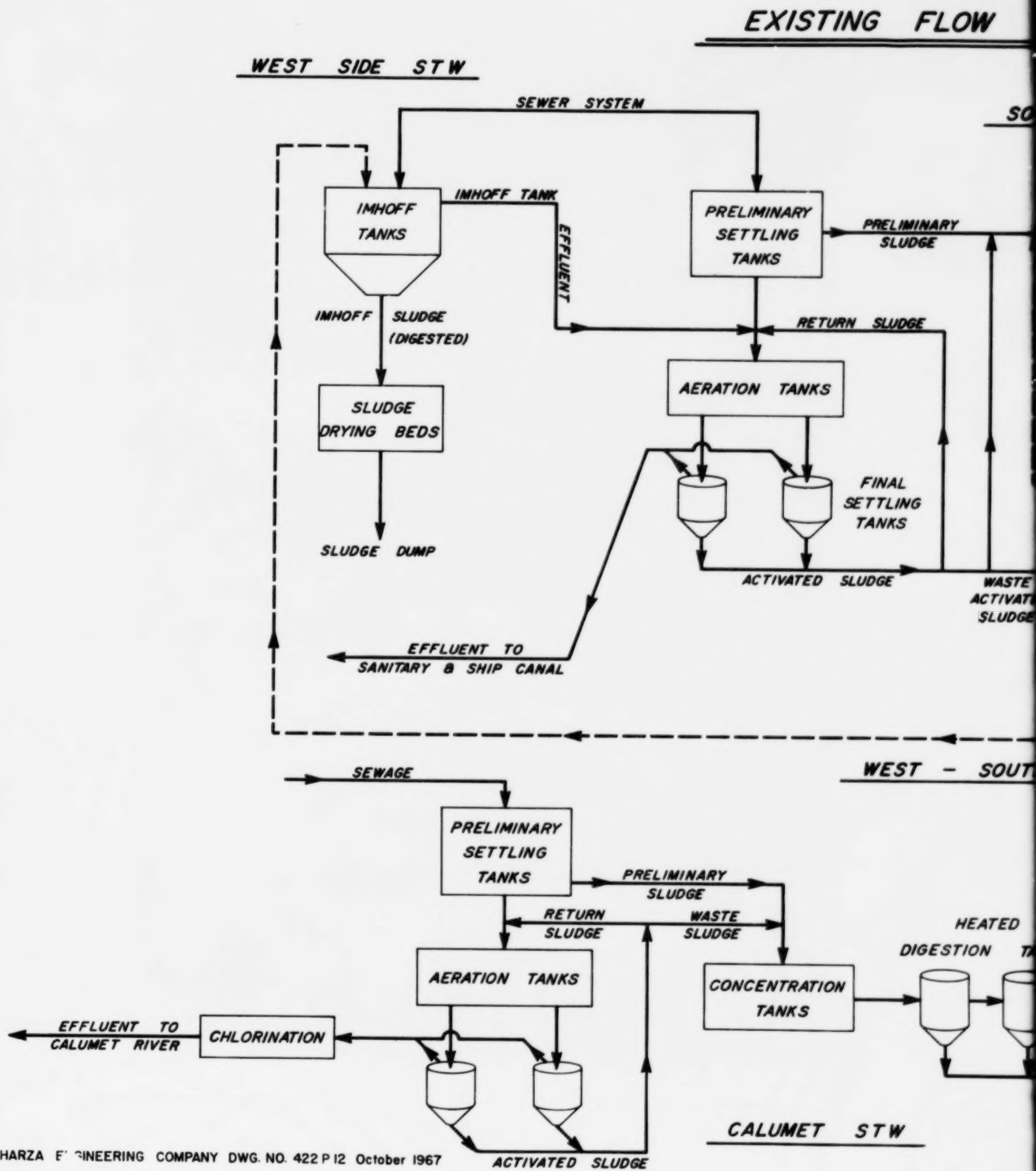
rated about 6-3-0.6. For comparison purposes, Milorganite (a dried sludge product of the City of Milwaukee) would have an analysis of about 6-4-0.5.

The effects of these nitrogen and other nutrient mineral values on soils and farm crops are discussed in Appendix C, and the possible effects on water resources are discussed in Appendix F.

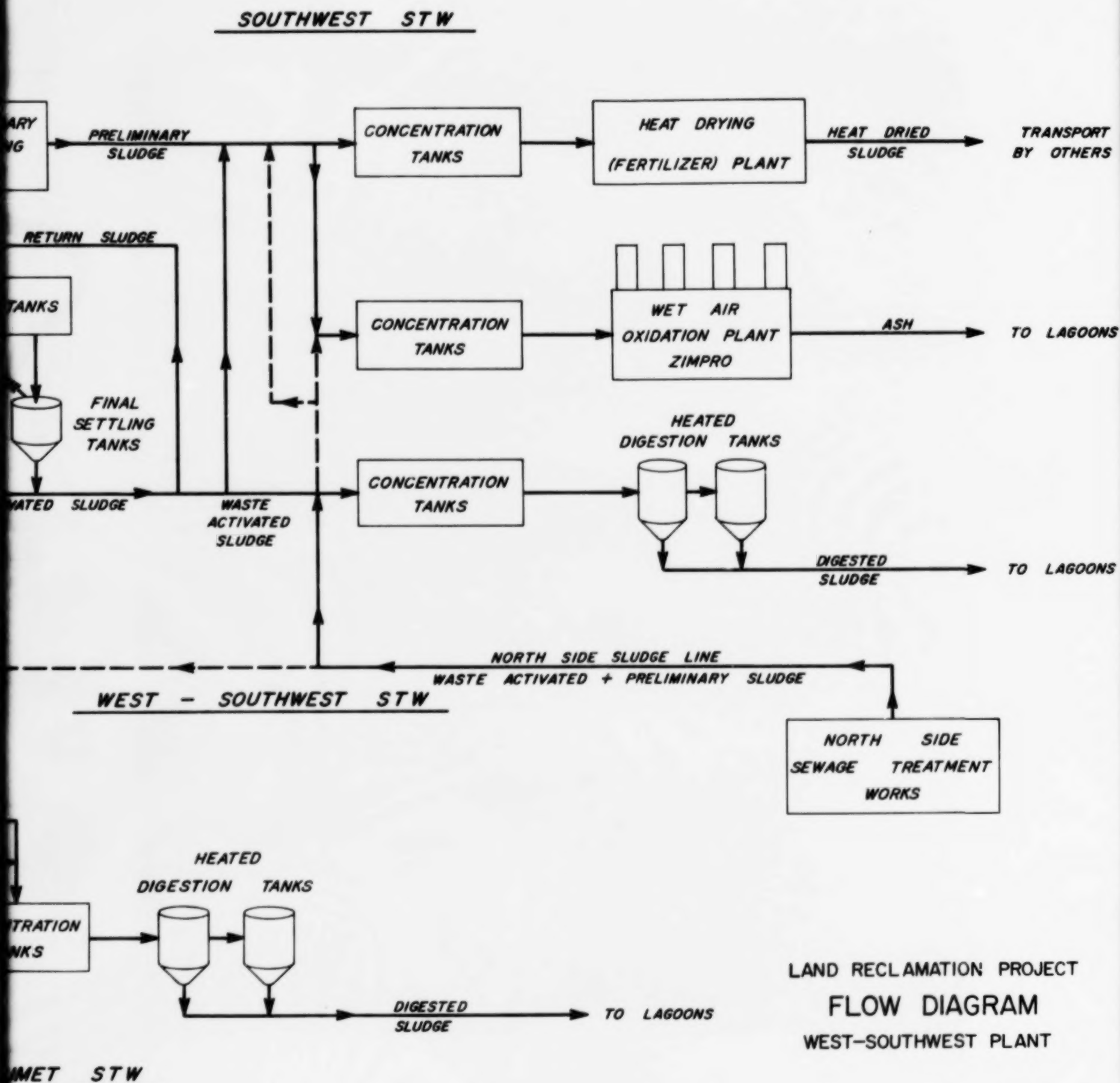
Other Constituents

The sludge contains other dissolved minerals which may effect plant growth or water resources. These also are discussed in Appendices C and F. In summary, these studies indicate that plant

and environment conditions should be monitored to assure that unsatisfactory conditions do not develop. However, no specific problems appear likely on the basis of present knowledge. Some further assurance is indicated by the fact that treatment plant biological processes are successful, and they depend upon somewhat similar chemical and physical conditions to those required for field crops.

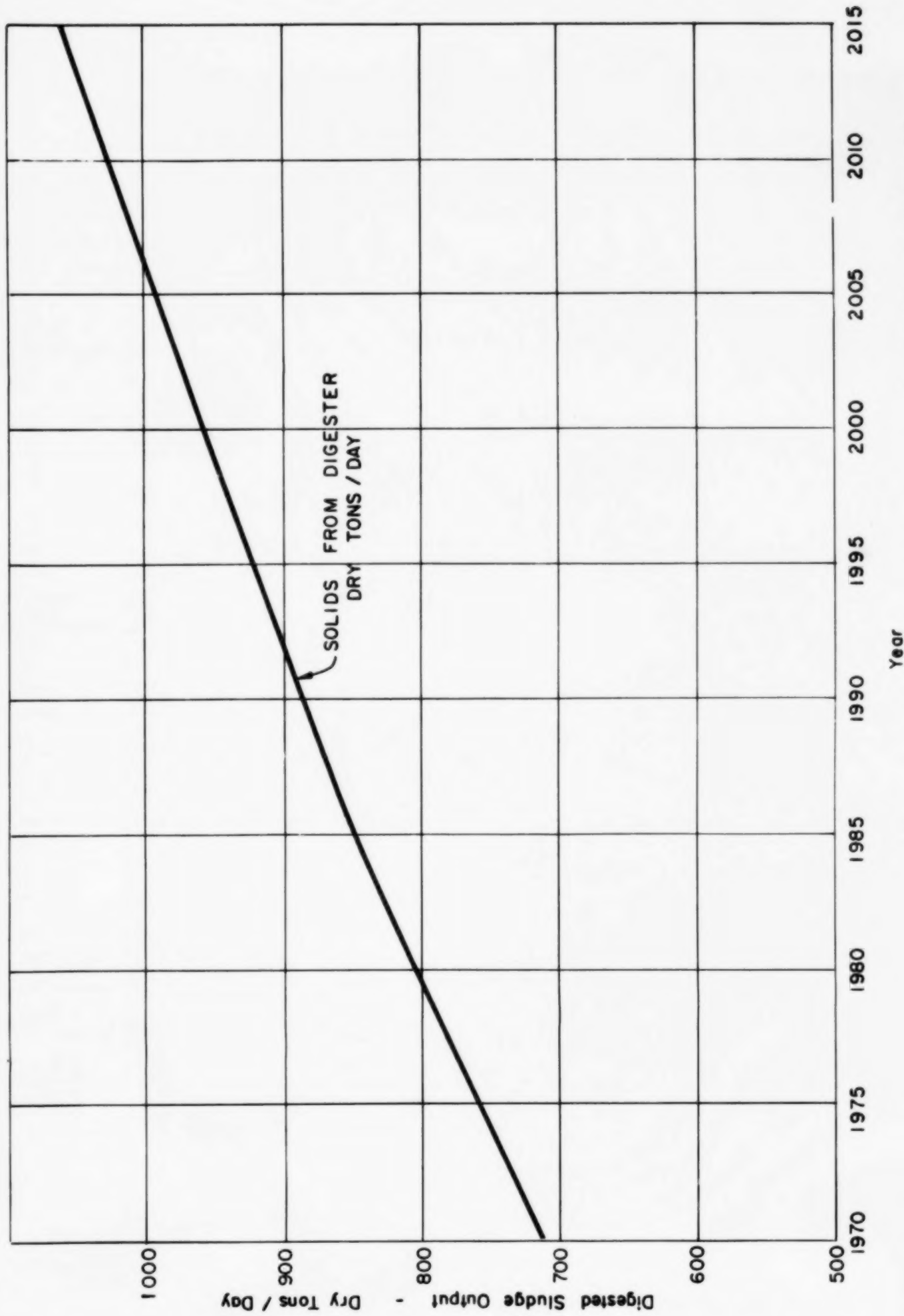


A

EXISTING FLOW DIAGRAM

B

EXHIBIT A-2



LAND RECLAMATION PROJECT
DIGESTED SLUDGE OUTPUT

HARZA ENGINEERING COMPANY DWG. NO 422P26 OCTOBER 1967

EXHIBIT A-3

	Units	CALUMET DIGESTER SLUDGE			W. SOUTH WEST DIGESTER SLUDGE			S. W. LAGOON DIGESTER SLUDGE
		7/66	7/66	6/67	7/66	7/66	6/67	6/67
Total Solids	mg/l	27500	29305	34300	22600	22430	29000	317,500
Mineral	mg/l	13200	13200	17800	10200	10200	14000	201,500
Organic	mg/l	14300	16105	16500	12400	12230	15000	116,000
Specific Gravity		-	-	1.011	-	-	1.002	1.126
pH		7.0	7.1	7.7	7.2	7.2	7.2	8.1
Maximum Part Size		-	-	10 mesh	-	-	20 mesh	-
Conductivity	umho	3800	3800	6000	3600	3600	5500	2000
Hexane Soluble	mg/l	1727	-	4200	1774	-	2700	17600
Alkalinity as CaCO ₃	mg/l	2745	2750	2460	2615	2600	2130	-
Al	mg/l	-	227	636	-	173	1345	28966
As	mg/l	-	BDL'	-	-	-	BDL'	BDL'
B	mg/l	0.9	1.9	5.1	1.2	1.1	0.9	14.0
Cd	mg/l	1.9	1.0	2.4	10.6	9.3	8.4	120
Ca	mg/l	1180	1240	-	811	845	-	-
Cl	mg/l	490	490	170	350	350	150	-
Cr	mg/l	46	49	26.0	81	79	88	860
Co	mg/l	-	-	BDL'	-	-	BDL'	BDL'
Cu	mg/l	32	24	31.0	46	49	47.4	690
Fe	mg/l	1666	1598	1500	662	661	1100	12500
K	mg/l	114	152	-	105	136	-	-
Mg	mg/l	332	291	446	228	249	194	240
Mn	mg/l	143	14	-	45	5	-	-
Mo	mg/l	-	0.06	BDL'	-	0.03	BDL'	BDL'
Total N	mg/l	1512	1450	1767	1542	1538	1753	-
Ammonia N	mg/l	528	603	790	608	657	736	1338
Na	mg/l	129	119	-	78	79	-	-
Ni	mg/l	Trace	2	3	10	12	13	116
P	mg/l	680	738	740	632	707	710	-
Pb	mg/l	90	90	6	19	19	19	20
Si	mg/l	-	9800	2773	-	5200	3129	43138
S	mg/l	45	67	288	52	82	306	1660
Zn	mg/l	92	91	90	147	148	191	1570

Note: ' Below Detectable Limits

LAND RECLAMATION PROJECT
TABULATION OF SLUDGE ANALYSIS

Appendix B

PRESENT KNOWLEDGE OF SLUDGE UTILIZATION FOR AGRICULTURE AND LAND RECLAMATION

Digested sewage sludge has been used for various agricultural and land reclamation purposes for many years and at many locations throughout the world. The available literature has been reviewed to learn as much as practicable, from the experience and research of others, for application in this report.

Summary of Findings

The literature research revealed that most installations apply liquid sludge by irrigation methods, although application techniques range from fire nozzles to dump trucks. Sludge is most frequently conveyed to the fields by tank truck or by pipelines. It has been applied at rates of 0.5 to 500 tons of dry solids per acre per year, T/A/Y, of dry solids in slurry concentrations of 1 to 10 percent dry solids. Application rates of 0.5 to 50 T/A/Y are reported where repeated annual loadings are used in conjunction with farm crops, which can utilize large amounts of nitrogen. Crop yields are improved almost as much as for comparable applications of mineral fertilizers.

Application rates of 50 to 500 T/A/Y are reported where massive (one-time) loadings are applied to sterile soil, such as dredged sand fill, for reclamation and development of a top soil to support vegetation. Extremely heavy applications, over 200 T/A/Y have been confined to dredged coastal areas where ground-water pollution is no problem, although no inland areas have reported such pollution.

None of the references reported serious nuisance or health hazards

as the result of utilizing digested sludge. Slight or temporary insect or odor conditions were experienced occasionally. Toxic soil conditions occurred where loadings were excessive or other agricultural-management needs had been neglected. Complaints were reported once for conditions where runoff had carried sludge into local streams; however, the sludge had been applied on land with slopes of 10 to 20 percent without diking. Many pathogenic organisms die off in digestion process, but some concern has been expressed about possible virus survival.

Locations of Agricultural and Reclamation Use

Sludge has been used for agricultural or similar operations under many diverse climatic and cropping conditions. A few of the locations which have been reported are shown in Table B-1.

Several cities in the midwestern United States are operating farms for sludge utilization. Canton, Ohio has the longest history of operation, with their farm having begun in 1900. Springfield, Illinois, has recently started an extensive farm-utilization operation. Many smaller cities throughout the United States are able to sell or give away part, or all, of their sludge to farmers located near the treatment plant. (Musgrave, 1967)^{1/} Several larger cities (Merz, 1957; and Scanlon, 1957) have used large amounts of sludge to reclaim dredge-sand or shell-fill areas.

In Britain, liquid sludge commonly is used on farm land for its fertilizer value, particularly among smaller treatment plants. (Coker, 1965). It has been estimated (Anon, 1956) that about 44 percent of the

^{1/} (Musgrave, 1967) - Refers to entry in Annotated Bibliography

Table B-1

SUMMARY OF SLUDGE UTILIZATION
FOR AGRICULTURAL PURPOSES

Location	Population	Sludge Production		Area Acres	Loading T/A ann.	Remarks
		T/da	T/yr.			
<u>Illinois</u>						
Anna	4,280	n. d.	^{1/} n. d.	n. d.	n. d.	Operated 10 years
Fairfield	6,360	0.3	110	200+	0.5	
Millstadt	1,830	n. d.	n. d.	n. d.	n. d.	
McLeansboro	2,950	n. d.	n. d.	n. d.	n. d.	
Olmstead	480	n. d.	n. d.	n. d.	n. d.	
Red Bud	1,940	n. d.	n. d.	n. d.	n. d.	Operated 3 years
Waterloo	3,800	n. d.	n. d.	n. d.	n. d.	
Kankakee	27,670	n. d.	n. d.	n. d.	n. d.	
Springfield	86,790	5.2	1,908	8	80+	
<u>Other U. S.</u>						
Canton, Ohio	113,631	5+	1,900	300	to 20	Operated since 1900
New York, NY	7,891,957	n. d.	n. d.	1400	90	Sand fill reclamation
San Diego, Cal.	800,000	50+	19,000	2000	to 410	Sand fill reclamation
Miami, Fla.	291,688	19	6,900	65	15+	Part used for sand
Marion, Ind.	37,854	n. d.	n. d.	n. d.	n. d.	fill reclamation
Richmond, Ind.	44,149	n. d.	n. d.	n. d.	n. d.	Spread by truck on farms for 10 yrs.
Anderson, Ind.	49,061	n. d.	n. d.	n. d.	n. d.	
Peru, Ind.	14,453	n. d.	n. d.	n. d.	n. d.	
South Bend, Ind.	135,000	n. d.	n. d.	n. d.	n. d.	
Manitowoc, Wis.	32,275	n. d.	n. d.	n. d.	5+	
Tonawanda, N. Y.	21,561	n. d.	n. d.	n. d.	n. d.	
<u>Foreign</u>						
E. Herts, UK	n. d.	n. d.	n. d.	n. d.	n. d.	Since 1954
W. Herts, UK	n. d.	14	5,000	n. d.	4	Since 1957 on var. farm
E. Kilbride, UK	49,000	1.3	490	374	1	Sold to farmers
Paris, France	n. d.	19.5	7,100	10,000	0.7	Op. 87yrs. for irrig.
Berlin, Germany	n. d.	n. d.	n. d.	n. d.	n. d.	with effluent

^{1/} n. d. - denotes no data available at this writing

Note - summary excludes some users reported in M. P. No. 2, Water Pollution Control Federation.

sludge produced in England and Wales is applied to agricultural land. Paris, France and Berlin, Germany both have irrigated farms with sewage. The farm in Paris includes about 10,000 acres and has been operated for 87 years. (Fouquet, 1967).

Sludge Conveyance and Application System

Common methods of liquid sludge conveyance and application include: (a) tank truck transport and application, (b) pipeline transport and surface spreading, (c) pipeline transport and sprinkler application, and (d) barge transport and sprinkler application.

Trucks are usually equipped with a splash plate or distribution manifold to spread the sludge. The sludge is spread on crop land before planting, on pasture or grain stubble or corn stalks after harvest. The tank truck method is particularly adapted to small treatment plants, such as those at Fairfield, Illinois, (Musgrave, 1967) and South Bend, Indiana. Trucks are also suited for areas where weather conditions permit the movement of heavy trucks on the field without seasonal interruptions. Some plants have built holding tanks to retain sludge temporarily when application is delayed by weather or other restraints.

San Diego, (Merz, 1956, 1957) hauled sludge by truck from the treatment plant to the land disposal area. Costs for the 21-mile round trip were reduced, from \$.0070 per gallon in 1955 to \$.0019 per gallon in 1960, by using faster loading and unloading equipment and by concentrating sludge. Later, transportation costs were reduced to one-fourth of trucking costs by building a pipeline to the disposal site. On the San Diego disposal site, furrows are plowed and filled about 18 inches deep with liquid sludge. The process is repeated after drying

until the desired amount of sludge, up to about 410 tons per acre, has been applied.

New York City uses barges and pipelines to transport large quantities of liquid sludge to several hundred acres of sandy soil. The sludge is applied to produce a depth of 18 inches and allowed to dry.

Sludge is conveyed to the fields by pipeline and applied by surface spreading at Springfield, Illinois and Canton, Ohio. Sprinkler irrigation equipment is connected by light-weight pipe to pumps mounted on the tanker trucks at some English operations. Sprinkler equipment also has been used for application of animal-manure slurries (Davis, 1964). Sprinkler equipment has been used at Penn State University for several years, applying treated effluent under all extremes of weather (Myers, 1966).

Sludge Utilization Factors

Application Rates

The rates of application commonly used are dependent upon whether the liquid sludge is being applied for (a) nitrogen-phosphate fertilizer properties, (b) soil conditioner value or, (c) disposal as the primary objective. The literature does not indicate any consistent approach to determine loading rates.

Fertilization

A farmer has used liquid sludge from the Fairfield, Illinois, plant for the last 10 years on parts of his 200 acres, using applications of about 0.5 ton per acre annually. Experience in England indicates application rates in the range of 1 to 10 tons per acre annually, although higher rates have been reported.

Several controlled tests have shown that application rates of from 2 to 25 tons per acre are satisfactory in supplying the nitrate and phosphate need of a subsequent crop. Lunt (1961) in his extensive work with digested sludge, recommends a rate of about 10 tons per acre, for a sludge containing about 2.5 percent total nitrogen. These trials were carried out on both sandy and medium textured soils. Other tests by Van Kleek (1953) suggested improved crop returns at the 10 ton acre rate, but no analysis was reported to indicate the nutrient content of this sludge.

Reclamation - Liquid sludge is reportedly used for the reclamation of dredged-sand fill at New York and San Diego. Applications are made at rates of 300 to 1,000 T/A. At New York, sludge is dried before plowing but at San Diego, wet sludge is plowed into the previously sterile sand to develop a "topsoil" capable to supporting vegetation. Topsoil had been trucked in to these areas previously at greater cost. Sludge is applied to dredged-shell fill at the Virginia Key Plant in Miami (Henry 1967). A relatively heavy load is applied initially, and repeated-annual loadings of about 14 T/A are maintained after grass cover is established.

Disposal - The annual application rate used at Canton, Ohio and Springfield, Illinois, are predicated by economic and esthetic disposal of liquid sludge, rather than optimum-nutrient utilization. The estimated average loading rate for the Canton farm is estimated at about 7 tons per acre annually, but because of an uneven distribution of applications some areas have probably received several times this annual rate. At Springfield, Illinois, annual loadings of 70 to 100 tons per acre are reported, although some losses have occurred due to runoff. Springfield also has applied bed-dried sludge to an adjoining

field at rates ranging up to 50 T/A/Y.

Crop Yield from Sludge Application - Few controlled experiments have been made to evaluate the improvements in crop yield resulting from sludge application. Sludges from different sources vary widely in physical and chemical properties, and differing responses have been obtained from a particular sludge on differing soils. Only a general evaluation can be given to the response which can be expected by a particular sludge on a particular soil. Crops in the controlled experiments cited have generally responded as well to the available nitrogen in sludge as to an equivalent chemical-fertilizer application.

Published results (Merz, 1956-1957) shown in Table B2 show barley yields for test cuttings from controlled experimental plots. The yield data are rather erratic, but they suggest that very high N or P levels were not harmful to the crop. The 100 ton loading rate would correspond to an application of 5,280 lb/A of total N (of which perhaps 1,800 lb. would be in available form) and 11,480 lb/A of phosphate (as P_2O_5). The range in yields may be due, in part, to poor germination caused by the high loading of soluble salts contained in the sludge and inadequate leaching of a high concentration of soluble salts.

Table B2
SAN DIEGO CROP YIELDS

<u>Sludge Loading</u> ^{1/} (Tijuana Tests, 1956)	<u>Grain Yields</u> ^{2/}	
	<u>Sludge only</u>	<u>Sludge plus fertilizer</u>
0	1.96	2.40
10	4.74	5.58
20	3.54	5.88
50	6.53	6.44
75	3.73	4.89
100	4.81	2.52

Table B2 (Cont'd.)
SAN DIEGO CROP YIELDS

<u>Sludge Loading</u> ^{1/}	<u>Sludge only</u>	<u>Sludge plus fertilizer</u> ^{3/}
<u>Treatment Plant Tests, 1957</u>		
0	0.76	-
0	-	3.82 ^{4/}
25	3.20	-
50	2.24	-
100	3.49	-

1/ In tons of dry solids per acre

2/ as lbs. -dry weight of Barley for 25 square foot cutting; average of 1 to 5 plots

3/ commercial fertilizer (Ammonium sulphate) equivalent to 40 lb/A of available N.

4/ commercial fertilizer only (Ammonium phosphate) equivalent to 64 lb/A available N; and 80 lb/A.

Apparently, no attempt was made in these tests to determine soil nutrient needs and apply an optimum combination of sludge and mineral fertilizers.

It was reported (Troemper and Peters 1967) that corn yields increased 22 and 95 percent in 2 years of operation of an area receiving liquid sludge from the Springfield plant. These results do not represent a valid test since (a) the control area also received sludge, (b) the control area was not terraced, while the liquid-sludge area was, and (c) no adjustment can be made of the benefit to the crop from the water received with the liquid sludge application.

Table B-3
SPRINGFIELD CORN YIELDS

<u>Year</u>	<u>Sludge Applied Tons/Acre</u>	<u>Corn Yield, Bn/Acre</u>	
		<u>Sludge Site</u>	<u>Control</u>
1965	106 ^{1/}	107	88 ^{2/}
1966 ^{3/}	67	76 ^{4/}	39 ^{5/}

-
- ^{1/} Some ran off to creek
^{2/} Received 55 T/A/Y of bed dried sludge
^{3/} Extremely dry year, except at harvest-wet conditions then caused loss
^{4/} Terraced land in Sludge Site
^{5/} Received up to T/A/Y bed dried sludge

Lunt (1959) has conducted the most extensive experimental tests of the effects of sludge upon plant yields. His studies indicate that sludge produces yield or growth results very near those obtained by comparable applications of mineral fertilizers. It appears that higher-yield results were possible if the sludge was leached prior to planting.

Other Effects on Soil

Sludge utilization has resulted in improvement of soil characteristics such as aggregation, cation-exchange capacity and permeability. Moisture retention is also improved, but available moisture is probably improved only slightly, if at all.

Lunt (1959) reports that the number of soil-aggregate particles above 1.0 mm size increased after moderate-sludge applications. Cation-exchange capacity increased for these same tests, and soil characteristics indicated an improvement in permeability. Merz (1956) and Lunt (1959) report improvements in moisture retention, but Lunt states that

moisture available to the plant increased only slightly. Another study (Klute, Jacobs, 1950) reports that applications of 40 tons per acre per year of horse manure resulted in an increase of only 20 percent in available moisture after 25 years of applications.

Operational Problems

There have been very few operating problems reported for the utilization of sludge on agricultural land. Several small plants report inconvenience due to the need for holding sludge when fields or roads are impassable. Transportation or application facilities have been changed, in many instances, to reduce operating costs or improve operational control. For example, it was necessary to modify the New York City transportation barges for sea disposal so that unloading could be accomplished in a short time at the reclamation sites, so that schedules could be maintained when the barges were diverted from their normal sea disposal circuit. San Diego reduced transportation costs by building a 7.5 mile pipeline to the principal point of application.

Health or Nuisance Conditions

No problems are reported in the literature of ground-water pollution from seepage or disagreeable odors or insects at farms using liquid sludge as described. In all probability incidents have occurred, due to the wide range of management which would prevail in a practice of the sort, but the incidents were not recognized because of the lack of monitoring.

Sludge has been washed off the utilization areas into streams at Springfield, Illinois and at Canton, Ohio, because both sites were on unlevelled-steep slopes without drainage confinement. Protective grading was done immediately after the wash-out at Springfield to im-

prove application distribution and retain surface runoff. At Canton (Walkenshaw, 1967), the situation continued for some time and caused complaints resulting in restriction of the sludge utilization program. The complaints apparently did not arise until the digestion and operational control deteriorated, even though there had been rainstorm erosion at the farm for some time.

These problems have not developed where adequate design, preparation and control were employed. For example, very heavy loadings were applied at San Diego without complaint or hazard. Odors were detectable, but did not cause complaints from the farmer living adjacent to the test plot. They reported (Merz, 1956) that the sludge utilization on fields did not cause a fly problem, although some flies were associated with a lagoon-application trial. Ground-water samples were collected and analyzed.

Annotated Bibliography

Anderson, M.S., "Comparative Analysis of Sewage Sludge", Sewage and Industrial Wastes, Vol. 28, No. 2, February 1961.

Most nitrification accomplished during a growing season takes place within a month after the sludge is incorporated with the soil. Sludge used had a nitrogen content of about 2-1/4 percent on a dry weight basis. After twelve weeks of incubation, 22 percent of nitrification had taken place; and this percent remained the same through sixteen weeks. The article states that the character of the soil to which the sludge is added and the crop to be grown will affect the nitrification percentage.

Anon, Use of Towns' Refuse in Agriculture. A study by the Natural Resources (Technical) Committee; Her Majesty's Stat. Off., London, England, 1954 ; Sewage and Ind. Wastes, 28, March 1956.

The dry solids recovered at sewage plants in England and Wales amount to 800,000 tons per year, and 350,000 tons are applied to agricultural land. Approximately 400,000 tons more could be used and this amount contains 10,000 tons of nitrogen, 5,000 tons of P₂O₅, and 1,200 tons of K₂O. Other organic matter added to the soil in normal farming, amounts to 17.5 million tons per year.

Bear, Firmen E., "The Wrong Turn," Journal of Soil and Water Conservation, October 1950.

Many weeds make highly important contributions in mobilizing minor elements in the soil. Ragweeds and Lambs Quarter, for example, are excellent accumulators of zinc. It is conceivable that they might be deliberately grown for the purpose of mobilizing this element.

Coker, E. G., Science Department, Hertfordshire Institute of Agriculture, "Experiments in East Hertfordshire on the Use of Liquid Digested Sludge as a Manure for Certain Farm Crops," Journal of the Institute of Sewage Purification, 1965.

Green and Cowling showed that the maximum amount of nitrogen which could be assimilated by grass was about 300 lb/acre per year and this was usually applied in two or three applications each of 100-150 lb. nitrogen. Since the nitrogen in liquid digested sludge is equally effective in increasing growth as that in fertilizers, this also defines the rate of application of liquid digested sludge for the most efficient production of grass. On the average the uptake of nitrogen from sludge was 86 percent of that equivalent artificial fertilizers; however, it is not stated whether or not this is based on the available N of the sludge.

Davis, E.H., Cattle Manure Handling and Disposal, Washington State University, Extension Manual 2416, 1964.

Several application systems are described, including sprinklers. A sprinkler manufactured in Germany is reported to prevent clogging, even when applying raw waste. Manure applications are followed by irrigation application to wash material off crop plants.

Favreau, A.E., Illinois Department of Public Health, Personal Communication, 1967.

The following is a list of the municipal sewage treatment plants in the southern region of Illinois disposing of sludge by lagooning or disposal on agricultural land. No nuisance or pollution has been reported.

<u>Sludge Lagoon</u>	<u>Liquid Disposal on Agricultural Land</u>
Benton	Anna
Carbondale N.E. plant	Fairfield
Cairo	Olmsted
Joppa	Red Bud
Summer	Waterloo

Fouquet, P., Chief Engineer, Paris Sewage Farm, Personal Communication, October, 1967.

The use of sewage sludge for a soil supplement has been practiced in Paris since 1880. Until 1940, the sewage farms received all the sewage from Paris and "... with proper management of the irrigation, no ponding of the sewage took place and no inconvenience was experienced in the neighborhood." The principal crops grown on these farms are celery, beans, and leeks but corn, rye and oats are also grown as well as many vegetables. The vegetables are noted for their size and color but persons buying them are instructed to boil them before eating.

Typical grain production rates are corn - 30 bu/ac., wheat - 25 bu/ac., and oats - 50 bu/ac. The Paris sewage farm occupies 10,000 acres of public and private lands and has an apparent application rate of 1.0 ton per acre per year.

Glaser, J.R. and Joe O. Ledbetter, Sizes and Numbers of Aerosols Generated by Activated Sludge, Water and Sewage Works, June, 1967.

The activated sludge process emits considerable numbers of aerosol particles. These particles may be inhaled or ingested by people in the vicinity of the treatment plant. Many of these particles have been proven to carry respiratory pathogenic bacteria.

Relatively large particles (10 microns) present little health hazard since they fall back into the aeration tank. About 40 percent of the particles have diameters less than 10 microns; these are respirable and could cause respiratory infections and disorders. No data is given to show the pathogen content of the aerosol particles.

Klute, A. and Jacobs, W.C., Physical Properties of Sassafras Silt Loam as Affected by Long-Time Organic Matter Additions Proceedings of Soil Science Society of America, Vol. 14, 1950.

Long term tests were conducted at Riverhead, Long Island on level plots of Sassafras Silt Loam. Manure loadings were applied at rates up to 40 tons dry solids annually for periods up to 40 years. Soil organic levels were increased to 2.5 to 5.0 percent and moisture holding capacity was increased by about 25 percent. However, available moisture was increased by less than 20 percent, since the wilting point had been increased also. The stability of 2 to 5 millimeter aggregates was improved significantly.

Leaver, Robert E., "Sludge Disposal Practices in the Pacific Northwest," Sewage and Industrial Wastes, 23, 323, March 1956.

A summary is presented of sludge disposal practices at several Northwest communities. Liquid sludge is disposed for fertilizer at four communities. At Olympia, a nurseman pays \$2.00 per 1000 gal load (\$4.80/dry ton) and hauls it away in his own truck a distance of 2-1/2 miles. Chehalis received \$400 per year for 142,000 gal of sludge in 1954 and at 7% solids the return was about \$10/dry ton. Issaquah has approximately 15,000 gals of thin digested sludge hauled each six weeks.

by a farmer who uses it on hay fields. At Shelton, private haulers have taken most of the available liquid digested sludge since 1951. A reference shows the constituents of various fertilizers. In Seattle, manure costs about \$16.60 per ton dry. Miloganite costs \$114 per ton. Portland, Oregon and Tacoma, Washington, lagoon liquid digested sludge. Some sludge was removed when the cities advertised its availability. The Washington State Health Department requirements state that raw or improperly digested sludge cannot be used nor can digested sludge be used on root crops or low growing vegetables, fruits, or berries. When used for hay fields, cattle must be excluded for 45 days. Air dried sludge must be dried for 30 days or until it can be handled with a pitch fork. Sludge may be used on root crops and vegetables if the sludge is plowed into the field six months prior to planting.

Lunt, Herbert A., Digested - Sewage Sludge for Soil Improvement, Connecticut Agricultural Experiment Station, Bulletin 622, April, 1959.

Application rate should be based more on the nitrogen content of sludge than on organic matter content. Acid sludges may be toxic to some crops when used on acid soils, but the harmful effects can be avoided by liming. Sludges can be used at rates of 30 to 50 tons per acre under some conditions, especially for such crops as small grains and grasses. These crops respond well to fairly heavy applications of sludge, even on acid soils. However, 10 tons per acre is a safer rate.

Meier, Bruce E., "Economics of Processing, Marketing, and Disposing of Sewage Sludge;" Trans. Sixth Annual Conference Sanitary Engineering, University of Kansas, Bulletin of Engineering and Arch. No. 37, 1956.

All methods of sewage sludge processing and disposal are described and examples are given of locations using each. In Nebraska it is common to provide sludge piping that will allow easy loading of trailer mounted tanks that will provide eventual disposal to agricultural lands. The greatest single problem in the sludge fertilizer business is developing and holding a market. Sludge lagoons can aid overloaded digesters and drying systems. By creating a community awareness of the sludge value as a soil conditioner and fertilizer, costs of sludge processing can be reduced.

Merz, Robert C; Continued Study of Waste Water Reclamation and Utilization, California State Water Pollution Control Board, Publication No. 15, 1956.

Primary sludge from the City of San Diego, digested at 85°C for 30 days, was used for barley grown on test sites. The studies indicated the following:

- (a) Increased fertility of soils was obtained at loadings from 10 to 100 tons of dry solids per acre, with no pronounced optimum indicated.
- (b) A deleterious effect on the soil and interference with plant growth can be avoided by adequate leaching of the soil of intolerant salinity introduced with the sludge.
- (c) Costs were substantially decreased for sludge disposal.
- (d) Composite soil samples showed an increase of saturation percentage from 27 to 50 for the 100 T/A loading.

The sludge was applied to the land, allowed to dry for 30 days, then plowed under. No public health problem or nuisance developed. There was a slight musty odor present when the sludge was spread, but this disappeared after two to three weeks.

Coli form organism tests of water from nearby wells 20 to 40 feet deep gave negative results. Tests conducted by the U. of C. at Berkeley and by the L. A. County Flood Control District at Azusa, showed Lodi sewage effluent essentially coliform-free after percolation through a few feet of soil. Inadequate data were provided to show the effects of dissolved minerals or nutrients on the ground water.

Merz, Robert C., ed. Third Report on Study of Waste Water Reclamation and Utilization, California Water Pollution Control Board, Publication No. 18, 1957.

Experiments to determine if sprinkler irrigation of golf courses using sewage effluent created a public health problem by releasing water-borne bacteria to the air. Thirty-six air samples were collected, of which 19 yielded positive results. Four of the 19 positive samples were collected within the limits of effective spray irrigation. The remaining 15 positive samples were all taken within the zone where mist from the sprinkler could be physically detected. No positive samples were obtained where mist was not detectable.

The bacteria are able to be air-borne only in moisture droplets. The only possible health hazard is in the spray or mist zone.

The San Diego tests were continued. Fly problems were observed for lagoon operation, during a period of favorable sludge moisture. Substantial interest was generated, and local farmers attempted to gain access to sludge. Test plots were operated on the treatment plant grounds with results similar to the previous year. Barley was grown, but no optimum loading was inferred. No attempt was made to provide a balanced-fertilizer application which had been matched to soil needs. Application was repeated at the Tijuana - Test Plots, after a "superior" crop of tomatoes had been grown on the area previously used. The only indication of results is an observation that sludge loadings as high as 100 T/A did not have any ill effects on plant growth.

Murphy, Larry, "Nitrate Has Become a Problem in Forages," Crops and Soils, 1964.

Murphy studies the accumulation of nitrate in orchard grass, fescue, brome grass, alfalfa, sudan grass, bluegrass, timothy and ladino over four growing seasons. Enough nitrate was found in all the forages to cause illnesses in animals. Nitrate content was most pronounced in forages grown on soil treated with 100 lbs. or more of nitrogen.

Musgrave, Ira, Superintendant of Sewage-Treatment Plant, Fairfield, Illinois Personal Communication, May 6, 1967.

Fairfield has been applying sludge to the same farm for 10 years. Two smaller farms have been recently added for standby, and other farmers are trying to get priorities for sludge.

General Data

Type of plant: Conventional Settling and Trickling Filter

Type of sludge: Heated digestion without mixing

Output: settled solids - 3,000 gpd

digested sludge - 1,500 gpd

- Digester operation:
1. try to hold in primary digesters for 45 days; then
 2. pull off to secondary holding digesters, and
 3. as it nears full, haul to farm.

Disposal: to 200-acre general farm with 80-90 acres standby

Application: by tanker truck with deflector plate, prior to plowing and on plowed ground, on idle pasture land as well. 0.46 tons per acre per year (dry solids).

Myers, E.A., "Engineering Problems in Year-Round Distribution of Waste Water." Proceedings of National Symposium on Animal Waste Management, American Society of Agricultural Engineers, May 1966.

Niles, A.H., "Sewage Sludge as a Fertilizer," Division of Sewage Disposal, Toledo, Ohio, 1954.

Quoting from the Michigan Technical Bulletin No. 132, "the nitrogen of the soil organic matter is transformed to ammonia and then to nitrites and finally to nitrates by means of the action of soil organisms. This process is known as nitrification". Nitrates are water soluble and unless assimilated by plants are easily washed through the soil. The use of sewage sludge is said to inhibit this leaching because of the moisture-holding properties of the sludge. Sandy soils are almost always deficient in nitrifying bacteria and certain colloidal conditions which are essential to plant growth.

Pennypacker, Stanley P., William E. Sopper, Louis T. Kardos "Renovation of Wastewater Effluent by Irrigation of Forest Lands" Journal of the Water Pollution Control Federation, February 1967.

This is a report on studies made at Pennsylvania State University. The effluent from the University Sewage Plant was applied by a sprinkler system to university agricultural land and forests. The BOD of the effluent was 17 to 18 mg/l. Total suspended solids of the effluent was 15 to 32 mg/l. The sprinkler system applied 0.25 inches per hour, the application rates were 1 inch per week and 2 inches per week.

The agricultural production revealed a very good increase in yields from effluent plus irrigation.

<u>Crop</u>	<u>Yield Increase</u>
Hay	139%
Corn Silage	39%
Corn Grain	78%
Oat Grain	70%

The following conclusions are drawn:

1. Once nitrates leave the root zone they cannot be removed by crops.
2. A tree crop did not remove nitrates.
3. Reed Canary grass removed more nitrogen than alfalfa.
4. Reed Canary grass can tolerate more water than alfalfa.
5. Pathogens have presented no problem to date.
6. By growing grass or corn, nitrogen fixation from the air is not a problem as it may be with alfalfa.
7. After three years of operation with an application of 170 inches of effluent, the renovation capacity of the soil was excellent.
8. Phosphorus, which is principally responsible for the eutrophication of lakes and streams, was removed resulting in water percolating to the ground water containing an average of 0.04 to 0.07 mg/l phosphorus.

Rand Development Corp. Economic Transport and Disposal of Sludge Slurries, November 15, 1965.

This report is concerned with the cost of transporting digested sludge at solids concentration of about 4% through pipelines to abandoned coal strip mines or land reclamation areas. The advantages of pipelines are:

- (1) Continuous operation
- (2) Low maintenance requirements
- (3) Low maintenance and operating costs

By far the major cost in pipeline transmission is the capital cost and this is sensitive to both interest rates and project life. Sludge from sewage treatment plants for one million people can be transmitted 100 mi. for approximately \$7.00 per dry ton, for four million people at \$3.50 per ton.

Rudolfs, W, L. Falk, R. Ragotzkie, Contamination of Vegetables Grown in Polluted Soil, Sewage and Industrial Wastes Vol. 23, No. 3, March 1951.

Tests were conducted to determine the survival of the coliform group, and the Samonella and Shigella species. The tomatoes were selected for the majority of the studies. Experiments were performed by growing crops on a sewage irrigation farm and on an ordinary farm where the vegetables received direct application of human excrement or suspension of coliform organisms. Control plots, receiving no sewage or coliform suspensions, were investigated for comparison.

The results show that if sewage irrigation or nightsoil application is stopped one month before harvest, the fruit, if eaten raw, would not be likely vectors for the transmission of human bacterial enteric diseases.

In the case of the parasitic amoeba, Endamoeba histolytica, resistant stages as cysts are formed, which enable the organism to survive under adverse conditions. The field studies were designed to stimulate the most favorable conditions possible for contamination of crops by E. histolytica. Both tomatoes and lettuce were used as test crops.

Vegetables grown on polluted soils may carry on their surfaces the eggs of worms parasitic to humans. Because the eggs are very resistant to conditions outside the host; it is conceivable that they may be found viable on the external parts of plants grown in polluted soil or receiving direct application of fecal material.

Dessication and sunlight are the greatest lethal factors to the development of Ascaris eggs. Although a reduction in number of eggs takes place, plants such as tomatoes or lettuces will not completely free themselves in one months time after contamination. However, the remaining eggs were unable to develop to the infective motile embryo stage.

Scanlon, Arthur "Utilization of Sewage Sludge for the Production of Topsoil, " Sewage and Industrial Wastes, August 1957.

New York City has four methods for disposing of digested sludge:

- (1) disposal at sea
- (2) drying beds

(3) spraying on sand covered landfill

(4) lagooning

Digested sludge was spread on a 180-acre area at Marine Park between 1936 and 1956. This land performed as a drying bed. The dried sludge was removed in 1956 and plowed into sand covered landfill to create topsoil in the other areas of the park.

Topsoil was also created by spraying sludge on sand covered landfill. The sludge was sprayed on 40 acres at a time at the rate of one gallon per square foot and then allowed to dry for two or three days before disking it into the upper nine inches of sand. About 16 applications were required to form four inches of topsoil.

Sludge is also piped to lagoons and the dry sludge from the lagoon is spread on the sand.

It was estimated it would cost \$3.50/cu. yd. to import topsoil; while it costs only \$2.50 to form topsoil from sludge, including transport costs.

Stephenson, R. J., "Availability of Nitrogen in Sewage Sludges," Chemical Branch Public Health Department, London, England, January 1955.

Sludge used was dried in a current of air without heat and without other treatment. Tests were carried out using four different soils but classifications of the soils were not given. Nitrogen availability ranged from 12% to 24% and in some cases increased up to a point then decreased and in others continually increased.

Troemper, A. Paul and Peters Jerry, Springfield, Illinois, Sanitary District, Personal Communication, 1967.

The Springfield, Illinois Sanitary District disposes a portion of its secondary digested sludge on 22.5 acres of land. Liquid sludge is spread on 8.0 acres of terraced hillside. Bed dried sludge is spread on 14.5 acres. The soil is a dark colored loess. In 1965, 795 tons of bed dried sludge was spread on 14.5 acres. In 1966, 8.7 in. of liquid sludge was applied per acre, 4.9 in. during July and August and 3.8 in. during the winter. At a concentration of 6.8 percent, this was an application rate of 67 tons per acre. An application of about 107 tons per acre had been made in 1965, before the tract had been terraced.

Van Kleeck, LeRoy W, "Utilization of Sewage Sludge, " Water and Sewage Works, Ref. Edition 1953.

The principal value of digested sludges, is the humus content resulting in increased moisture-holding capacity of the soil and a change in soil structure which results in a greater friability. Like all humus materials, sludge stimulates the growth and propagation of angle worms which aid in soil aeration.

The author's own experience using an elutriated digested sludge conditioned with ferric chloride is that liming is required about every three years to maintain a soil pH between 6.5 and 7.0. Following are some of the reasons for liming:

1. Lime neutralizes excessive acidity.
2. It favors decomposition of the organic matter by bacteria.
3. It will improve the physical condition of heavy soils.
4. It supplies calcium, one of the elements needed by plants.
5. It makes phosphorus in the soil more available.
6. It increases the effectiveness of organic materials (sludge) and commercial fertilizers.
7. Lime will precipitate certain elements such as copper, aluminum, manganese, or zinc, which are sometimes present in excessive amounts, thereby reducing their solubility in the soil and preventing harmful effects.

The author found that first crop yields are improved by low application rates of sludge to soils. He found a rate of 10 tons per acre was better than a rate of 20 tons per acre.

Walkenshaw, G. B., Superintendent, Sewage Treatment Plant, Canton, Ohio. Personal Communication, May 23, 1967.

Canton has been disposing of its sludge since 1900 on 600 acres. The sludge is spread on approximately one-half of this area which is hilly and is used for pasture or is wooded. Sludge is not applied to the other, flatter land on which corn is planted. The land on which sludge is applied

has slopes from 10 to 20 percent. The sludge has been distributed by pumping to ditches along the top of the slopes and releasing it down the slope. Some sludge ran off into natural drainage channels and off the land, but there were no complaints except after a heavy rain following the sludge distribution.

The sludge production figures for the first three months of this year indicate a loading of about 7 dry tons per acre per year. The distribution was very uneven and small areas have probably received five to ten times this much. On a recently terraced area, 20 dry tons per acre per year have been applied.

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Appendix C

SOIL CONSIDERATIONS

General

Soils in northeastern Illinois are formed in glacial deposits including till, outwash, and glacial lake sediments. In places, such as in Will County, a thin layer of windblown silt (loess) mantles underlying till deposits.

The Coal City, Essex, and St. Anne sites are situated on a nearly level plain (the "Kankakee Plain") of sandy outwash and lakebed sediments. The Andres site in Will County is located on rolling morainic topography (the "Manhattan Moraine"). The glacial till of this latter area is a silty clay loam containing on the average four percent gravel, 12 percent sand, 53 percent silt, and 30 percent clay. It is mainly about 100 to 150 feet thick, but in places may be thinner and may have lenses of stratified gravelly materials ^{1/}.

Soils of the Phase II (Tinley Park) Site occur primarily on flat topography of a slope of one percent or less. The surface of these soils has a silty clay loam texture developed from calcareous fine textured lakebed sediments. This soil covers 90 percent of the area and occurs throughout the area. The soils that make up the remaining 10 percent are of a silt loam texture. They are developed from fine textured calcareous material of glacial till and lakebed sediments. The slopes of these soils will range from 1 to 3 percent.

The Tinley Park Site is similar to the Andres Site in soil characteristics and fertility.

^{1/} "Will County Soils," Soil Report No. 80, University of Illinois Agri. Exp. Sta., 1962.

Soils of Alternative Sites

Coal City Site

Soils of this site are composed primarily of broad, nearly level, areas of sandy loam soils, as shown on Exhibit C-1. A few sand ridges occur in the southern portion of the area and also near Coal City. Along the Mazon River recent silt and clay deposits produce medium to fine textured soils. The same soil texture occurs in small areas west of the Mazon River from exposures of glacial till. A minor fraction of the land is occupied by mine dumps.

The dunes, and lands near the river, have the greatest relief with slope gradients generally less than 5 percent. About 80 percent of the site is nearly level. The central area of the site is essentially flat and uninterrupted by surface drainageways.

Sandy loam soils in the central area have subsoils of sandy clay loam or clay loam with good moisture holding capacity. Surface horizons tend to be droughty with good infiltration; consequently, once a growing crop is established, it is maintained by moisture from the subsoil.

The sandy loam soils are highly productive and easily managed; present land use is chiefly for corn and soybean production. The Coal City site is the most productive of the four sites because of its favorable topography and soil properties.

Essex Site

Soils of the Essex site are shown on Exhibit C-2. They are mainly sands and sandy loams, together they comprise nearly 90 percent of the area. In contrast to the Coal City site, the soil pattern is more complex. Bodies of sandy loam soils are interspersed with sand ridges. Many poorly drained depressions exist throughout the central portion on either side of Horse Creek. The finer textured silt loam and loam soils occur mainly in low-lying areas adjacent to Horse Creek. Dune ridges are

conspicuous in the northwestern part and widely scattered throughout the rest of the area.

About 50 percent of the area is nearly level, 30 percent is gently rolling, and 20 percent is rolling. The rolling topography, which has slopes in excess of 8 percent, is associated chiefly with the dune ridges and slope breaks near Horse Creek.

Present land use is mainly for corn and soybean production but, with the exception of areas of fairly level well-drained sandy loam soils in the northeastern and east-central parts, crop stands are spotty this season. This is due to excessive wetness in the low swales and droughty conditions on the crests of sandy ridges. Because of uneven topography, varying soil conditions, and inadequate drainage, land management is difficult. Productivity is considerably lower than at the Coal City site.

Drainage and land leveling requirements are greater than at Coal City if the site is to receive sludge applications. However, it may be expected that productivity would be enhanced more because of sludge application and provision of drainage. It also has the advantage of being composed of essentially a single watershed.

St. Anne Site

This site has the highest proportion of sandy soils, about 60 percent of the entire area, as shown on Exhibit C-3. Included are flat low-lying sandy soils in the northwestern and central portions of the area, and rolling sand dunes in the eastern portion. The dunes are composed of droughty sands with rapid infiltration and permeability rates. Generally, these sandy areas are covered by sparse oak forest. The dunes are

very susceptible to wind erosion where they have been cleared; and, because of their excessive slopes and internal drainage, they are not adapted to row crops.

Fine textured silt loam, silty clay loam, and clay soils are scattered along Beaver Creek, with an extensive area occurring between Beaver and Little Beaver Creeks in the southwestern part of the site. These soils are formed in old lake clays and are slowly permeable, poorly drained soils.

Essentially all level land with surface drainage is being utilized for row-crop agriculture. In several of the flat sandy areas with high ground-water levels, corn production is being increased substantially by subirrigation, using water obtained and controlled by pumping from wells.

Some land in the site is not suited for cropping either because of excessive wetness or excessive droughtiness and slope. Where attempts are made to crop such land, yields are uneconomical.

Drainage, leveling, and amendments of soil properties by the addition of sludge or other high-organic material, combined with irrigation, would substantially increase soil productivity at the St. Anne site.

Andres Site

The soils of the Andres site are shown on Exhibit C-4. They are fine textured silt loam and silty clay loam types occupying nearly all of the area. Although the soil pattern is complex, the soils present are mainly of two types: the Elliott silt loam, which occurs on the crests of hills, and the Ashkum silty clay loam, which occupies the lower slope positions and depressional areas along intermittent drainageways. The Elliott soils have

moderate infiltration rates and the Ashkum soils moderate to slow infiltration. Both have slowly permeably silty clay subsoils.

The surface drainage pattern is fairly well developed but poor subsurface drainage causes wet soils for long periods in the spring and following heavy rainfall. Broad areas of uniform soil drainage conditions do not exist because of the varying drainage pattern.

The site also differs topographically from the others in that it is more rolling. Only 30 percent of the area is classed as level, 50 percent as gently rolling, and 20 percent as rolling. Thus, 70 percent of the area has slope gradients of from 3 to 12 percent.

Sloping conditions, together with slower infiltration rates, make surface runoff a greater problem here than at other sites. On the other hand, the slowly permeable subsoils and greater absorption properties associated with the higher clay contents in these soils make them much more effective in holding nitrogenous applications. Movement of water from the soil zone to the ground-water may be expected to be very slow. Also, plant roots do not readily penetrate more than a few inches into the unleached till.

The inherent fertility of these soils is high and yields of corn are very good. The primary handicap to farming is the somewhat excessive slope. This requires special management in order to avoid undue erosion. These soils have good moisture holding capacity, but in wet seasons slow drainage may delay farming or produce poor crop stands.

Sludge-Soil Interactions

Sewage sludge applied to soils will change the physical and chemical properties of the soil. The extent of change depends on the initial properties of the soils, sludge composition, and the duration and rates of sludge application.

Estimates of immediate and short-term (less than about 50 years) effects of sludge on soil properties are based on existing knowledge of soil compositions and the chemical, bio-chemical, and physical systems operative in natural soils. Properties considered are those which affect the ability of soils to absorb potential pollutants contained within sludge, and also properties that must be considered in managing reclamation lands for agriculture on a continuing basis.

Little information exists, either observational or experimental, regarding long-term effects of sludge applications on soils. Consequently, estimates made about conditions that may develop over periods of more than about 50 years must be considered speculative.

Benefits that may accrue as a result of applying sludge to soils are (1) improved soil structure (aggregation), (2) increased permeability of fine textured soils owing to improved structure, (3) decreased permeability of sandy soils due to increase in content of fine particles (4) some increase in available moisture holding capacity of sandy soils, (5) decreased susceptibility to erosion, and (6) increased absorptive capacity.

Sludge also will contribute major plant nutrients and micro-nutrients. The nutritional aspects of sludge-soil mixtures are discussed elsewhere in this report.

On the deficit side is the addition of inorganic salts, heavy metals, nitrogen compounds, and perhaps micro-organisms that exceed crop needs or are deleterious to soil properties. Some are leached out of the soil while others may be absorbed. In some cases accumulations may be detrimental to plant growth, e. g. , toxic levels of heavy metals may result from prolonged sludge application. Sludge applications, even at relatively light rates, add amounts of nitrogen that are in excess of crop needs. This leads to potential pollution of ground water by nitrate-nitrogen, a problem which is discussed in Appendix F.

It is further emphasized that, while certain soil properties benefit from light or short-term application of sludge, continued heavy applications such as 20 tons per acre per year may eventually become detrimental to these same properties. For example, sludge applied on sandy soils will reduce permeability and increase subsoil moisture storage in the root zone, but continued sludge application may reduce permeability to a point where subsoil drainage becomes inadequate.

Heavy Metal Effects on Soil

The accumulation of heavy metals (zinc, copper, chromium and nickel) from continued sludge application may eventually lower crop yields to uneconomical levels. While applications of lime can correct heavy metal toxicities by precipitating the metals in forms not available to plants, total concentrations in the soil will be

increased continually. Because some ions will always remain unprecipitated the level of available ions eventually will reach a toxic level for plants even though the available fraction represents only a very small percentage of the total.

The heavy metal concentrations in digested sludge are shown in Exhibit C-5. Inspection of that exhibit suggests that the elements most likely to accumulate to toxic concentrations are zinc, copper, and possibly chromium and nickel. Exhibit C-6 shows estimates that have been made which support this conclusion. Since zinc appears to be the most likely element to constitute a problem, it is discussed in greater detail below.

The values in Exhibit C-6 are estimates of heavy metal concentrations that might accumulate in the plow layer (upper six-inch layer of soil). Roots of most agronomic plants, however, are abundant throughout the upper 18 inches of soil. They also may penetrate to greater depths, but the bulk of the nutrients utilized by the plants are assimilated from the soil at the shallower depths. Growing plants could be harmed if concentrations of heavy metals exceed toxicity thresholds in any substantial part of the 18-inch layer. But because the heavy metals are chiefly complexed by organic matter their greatest accumulation is most apt to be in the plow layer unless deep tillage is regularly practiced. If sludge is uniformly mixed into a thicker soil layer more sludge can be applied before the added heavy metals reach toxic levels.

Instances of zinc excess or toxicity to field crops have been known for some time^{2/}. Buckman and Brady^{3/} state that restriction

^{2/} "Diagnostic Criteria for Plants and Soils," Chapman, H. D. University of California, Division of Agricultural Sciences, 1966.

^{3/} "The Nature and Properties of Soils," Buckman, H. O. and N. C. Brady, Macmillan Co., New York, 1960.

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The accumulation of heavy metals (zinc, copper, chromium and nickel) from continued sludge application may eventually lower crop yields to uneconomical levels. While applications of lime can correct heavy metal toxicities by precipitating the metals in forms not available to plants, total concentrations in the soil will be

increased continually. Because some ions will always remain unprecipitated the level of available ions eventually will reach a toxic level for plants even though the available fraction represents only a very small percentage of the total.

The heavy metal concentrations in digested sludge are shown in Exhibit C-5. Inspection of that exhibit suggests that the elements most likely to accumulate to toxic concentrations are zinc, copper, and possibly chromium and nickel. Exhibit C-6 shows estimates that have been made which support this conclusion. Since zinc appears to be the most likely element to constitute a problem, it is discussed in greater detail below.

The values in Exhibit C-6 are estimates of heavy metal concentrations that might accumulate in the plow layer (upper six-inch layer of soil). Roots of most agronomic plants, however, are abundant throughout the upper 18 inches of soil. They also may penetrate to greater depths, but the bulk of the nutrients utilized by the plants are assimilated from the soil at the shallower depths. Growing plants could be harmed if concentrations of heavy metals exceed toxicity thresholds in any substantial part of the 18-inch layer. But because the heavy metals are chiefly complexed by organic matter their greatest accumulation is most apt to be in the plow layer unless deep tillage is regularly practiced. If sludge is uniformly mixed into a thicker soil layer more sludge can be applied before the added heavy metals reach toxic levels.

Instances of zinc excess or toxicity to field crops have been known for some time^{2/}. Buckman and Brady^{3/} state that restriction

^{2/} "Diagnostic Criteria for Plants and Soils," Chapman, H. D. University of California, Division of Agricultural Sciences, 1966.

^{3/} "The Nature and Properties of Soils," Buckman, H. O. and N. C. Brady, Macmillan Co., New York, 1960.

of plant growth brought about by excess of Zn can arise in acid soils in certain areas but is more likely to be caused by addition of Zn-rich materials such as sewage sludge.

Rohde (1962) attributes decreased yields on sewage-irrigated farms at Berlin and Paris to the accumulation of high concentration of copper and zinc in the soil, (Exhibit C-7). Since Rohde's work appears to be the only well documented report of heavy metal toxicity to plants induced by the application of sewage to agricultural land it is worthwhile to review it more fully ^{4, 5/}:

After many years of sewage disposal by irrigation on cropland near Berlin and Paris the lands began showing signs of exhaustion and decreased crop yields following earlier high yields. (It is reported that applications at Paris have been made for 87 years.) In 1957 soil samples were collected from land on which healthy plants were growing and also from lands showing exhaustion at both Berlin and Paris. Soils at the Berlin sewage farm are sandy and acid (pH 5.2-6.3) while those at Paris were near neutral (pH 6.7-7.3) and rich in lime. Soils on land showing signs of exhaustion contained more organic matter than soil from land on which healthy plants were growing, suggesting that the amount of sewage sludge in the soil was an important factor. Some soil organic matter contents reported are: 2.2% (in soils with healthy plants) vs. 7.1% (adjacent soils with unhealthy plants), 3.7% (healthy) vs. 8.9% (unhealthy), and 1.8% (healthy) vs. 3.45% (unhealthy). ^{6/}

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- ^{4/} "The effects of trace elements on the exhaustion of sewage-irrigated land," Rohde, G., Journ. Inst. Sew. Purif. Part 6:581-585, 1962.
- ^{5/} The behavior of zinc and copper in soils and as a plant micro-nutrient are similar. Also it appears that copper may reach toxic levels at about the same time as zinc with heavy sludge applications. For these reasons Rohde's data on copper are also included.
- ^{6/} Rohde used weight loss on ignition to estimate organic matter content. This method causes loss of water from hydrated clay minerals, thus, values for organic matter are somewhat in excess of actual.

Rohde investigated the status of several "trace elements", but he concluded that zinc and copper were the chief depressants to plant growth on the sewage farms. Data in the table below on zinc and copper concentrations are taken from Rohde.

Normal Zinc Contents in Soils. The normal total zinc content in soils ranges from 10 to 300 ppm; a typical value is 100 ppm. Zinc is usually more concentrated in surface than in subsurface soil horizons. Available zinc (ZH_4OAC - extracted) normally is in the range of about 0.5 to 5.0 ppm. Water soluble zinc is in the parts per billion range.

Zinc in soils is largely in organic complexes; some is held as exchangeable Zn on cation exchange sites of clay minerals. The latter form is probably the form most available to plants. Deficiencies occur when available zinc falls below 0.5 ppm.

Zinc may be fixed in small amounts by silicate clays, and it may precipitate as the phosphate, carbonate, or hydroxide at slightly acid to alkaline pH. Hence, liming is often used to relieve zinc toxicity to plants. Liming can however, create other problems insofar as plant growth is concerned, since the availability of other necessary plant nutrients are curtailed at alkaline pH values. Also, excessive plant uptake of molybdenum, so far as forage for animals is concerned, normally occurs on neutral or alkaline soils^{7/}.

^{7/} "Chemistry of the Soil," Bear, F. E. ed, Reinhold Publishing Corporation, New York, p. 280, 1955.

Zinc Uptake by Plants. Plants of different kinds will show zinc contents in the dry matter from less than 20 ppm to 10,200 ppm,^{8/} showing that different plants have a wide range in capacity to take up zinc. Those that can assimilate large amounts of zinc (e.g. ragweed) can be used by analyzing their tissue to indicate zinc excess in soils. Zinc levels in plants showing deficiency symptoms contain less than 20 to 25 ppm in the dry matter. Ample but not excessive levels commonly fall in the range of 25 to 150 ppm. Data on excess levels are very meager, but the information at hand indicates that amounts greater than 400 ppm in plant dry matter may indicate zinc excess. In Jo Daviess County, Illinois, an area of zinc mines, corn showed stunting and other toxicity symptoms. Tissue analyses of this corn indicated zinc concentrations of 200 to 300 ppm^{9/}.

If a crop had a concentration of 100 ppm zinc in dry matter, a 10 ton per acre crop would remove amounts to 1 ppm or 2 pounds zinc per acre; however, since zinc occurs chiefly in the leaves of corn, removal of only grain will not significantly deplete zinc supplies in the soil.

Zinc Additions to Soil From Sludge Application. Assuming that sludge contains 5000 ppm zinc (dry basis) and is applied at a rate of 20 tons per acre per year, the annual addition to the soil is 200 pounds of zinc per acre (100 ppm). Much of this is probably in organic complexes (chelated)

^{8/} Chapman, H. D., op cit.

^{9/} Personal communication, Dr. Ted Peck, University of Illinois Department of Agronomy.

and some is undoubtedly precipitated in the phosphate, carbonate, and possibly silicate form. Liming soils that have received sludge applications will favor zinc precipitation and thus render it in a form that cannot be assimilated by plants and (resultant possible toxic effects.)

If it is assumed that 0.1% of the total zinc is soluble and that sludge is applied for 50 years at the 20 tons per acre per year-rate the total at the end of this time would be 5000 ppm (ignoring native soil zinc) and the soluble fraction would be 5 ppm, a level (from Rohde's data) that is probably toxic to corn.

Discussion. The unknown in making an appraisal of possible zinc toxicities to plants induced by long term applications of sludge are:

- (a) The average zinc concentration of the sludge over a long period of time.
- (b) The distribution of zinc in organic complexes, various precipitates, exchangeable form, water soluble form, etc., in the sludge.
- (c) The extent to which liming (maintaining slightly alkaline pH) could be effective in preventing zinc toxicity to plants. The useful duration of lime additions for removal and its potential effect on plants. (Generally the most favorable pH to most crops is 6.0 to 6.5).
- (d) Assuming that lime reacts with zinc to form zinc carbonate the ratio of soluble zinc and the variation in soluble zinc should be determined.

Additional laboratory analyses should be made to establish the average zinc content in Chicago sludge and also give a better picture of the forms in which it occurs and its distribution.

Carefully controlled field experiments conducted over a minimum of three to five years can provide information useful in establishing trends in zinc availability to plants on sludge lands. Zinc determinations in plant tissue obtained from crops grown on this land will show gradual increases in contents if liming does not effectively reduce zinc availability. These experiments could be incorporated in the University of Illinois research program.

Judging from Rohde's report, which suggests that a near neutral pH at the Paris sewage farm was not sufficient to prevent zinc and copper toxicities following 87 years of sewage application, liming will not be effective in a long-term operation.

Recommendations. Steps should be taken at the Phase 1 and 2 Site to maintain surveillance of concentrations of heavy metals, particularly zinc, copper, and chromium, in plant tissue collected from crops. If these tests indicate that toxic metal concentrations are being developed, steps also should be taken to locate the origins of these metals. Necessary remedial action should be taken to reduce application rates to levels which would prevent toxic levels in the soil.

Effects on Soil Texture

One of the chief properties determining soil behavior and use is the texture and particle size distribution. Soils are made up of mixtures of particles ranging in size from clay to gravels and boulders.

The "fine earth fraction" is that portion of soil material having particle size diameters of less than 2 mm.; this fraction is further subdivided into clay, silt, and sand. The clay, or colloidal fraction may be considered the active portion while silt, sand, and larger particle-size fractions are relatively inert insofar as chemical and moisture-holding properties are concerned. Well decomposed organic matter (humus) in soils exists chiefly in the colloidal fraction and strongly affects soil properties when present in moderate amounts.

Because of the great differences in the behavior of sandy soils and clayey soils, consideration is given to the effects of sludge on sandy soils that contain less than 10 percent clay and to silty clay loam soils that contain about 30 to 40 percent clay. Sandy and silty clay loam soils represent generally the coarse, and fine textured extremes of the range of textural soil types that occur in the areas being considered in Northeastern Illinois as possible sludge disposal sites. Analytical data for some typical soils representing the sandy and silty clay loam types and two intermediate textures are given in Exhibit C-8.

Comparisons of the effects of sludge on the properties of sandy, and silty clay loam soils are summarized in Exhibit C-9; which shows that the physical effects of sludge utilization may favor sandy soils and the chemical effects probably favor finer soils. Effects of sludge on soils of intermediate textures, viz., sandy loams, silt loams, loams, and clay loams will be between the values described on Exhibit C-9. These points of comparison have been used to evaluate the suitability of the four alternative sites, as discussed below:

Comparison of Alternative Sites

Basis of Comparison

From a purely physical standpoint there are three main considerations in selecting land for sludge disposal. They are:

- (a) Soil areas that offer maximum absorption of sludge constituents
 - (1) to prevent pollution of ground water
 - (2) to hold plant nutrients and render excess amounts of possibly toxic (to plants) constituents in an unavailable form.
- (b) Soil areas that offer maximum infiltration (thick permeable strata)
 - (1) to provide needed underdrainage to take care of water added from heavy loading of sludge, so as to prevent surface runoff and have a surface dry enough so agricultural operations may be performed.
 - (2) to filter out particulate matter and provide a thick zone favorable for aerobic bacterial activity.
- (c) Soil areas that have favorable topography for sludge disposal systems and farming operations.

Soil conditions that favor maximum absorption are in contrast to those offering maximum infiltration and permeability. The advantages of favorable topography, i. e. , level or gently sloping lands are the

same with soil areas of maximum absorption or soil areas of maximum infiltration. Thus, the choice is between areas of maximum absorption or areas of maximum infiltration. Land areas with maximum infiltration rates hold distinct advantages for a land reclamation plan that includes an effective farming operation, because these lands offer the possibility of maximum sludge loading rates without greatly interfering with the farming operation. A distinct disadvantage, however, is the danger of pollution to ground water, because the operation of a permanent reclamation site will require leaching of soluble salts from the root zone. If this danger can be guarded against with a fair degree of reliability, then it can be accepted that a soil area offering maximum infiltration and permeability should be selected.

Discussion

In addition to having lower infiltration capacities, the Andres Site has rolling topography and sludge application to this land would be difficult and would probably not significantly increase productivity. The principle soils and land characteristics for each Phase 3 site and the Phase 2 site have been summarized in Exhibit C-10. This Exhibit also provides a summary of estimated ratings of the Phase 3 sites on the basis of these and other points. In selecting a site from the four alternatives, the chief considerations from the soils standpoint include:

- (a) Which sites offers the best protection of water resources?
- (b) Which site presents the least difficulty in laying out a sludge application system and companion farming operation?
- (c) Which site would benefit most from sludge application and the attendant construction necessary for land reclamation and a successful farming operation?

Comparing the three sandy soil sites on these points produces the following conclusion:

(a) Ground water pollution hazard.

The Coal City site has, overall, the least permeable soils and thus offers more absorption with relatively deep ground water tables offering less opportunity for pollution.

There are more highly permeable soils at St. Anne and water tables are higher over more of the area than at the Essex site. Hence, the Coal City site appears to be best from the ground water pollution point.

(b) The Coal City site would be least costly to develop a reclamation plan because of the level topography. Essex and St. Anne sites are about equal and would require somewhat more land leveling than at the Coal City site.

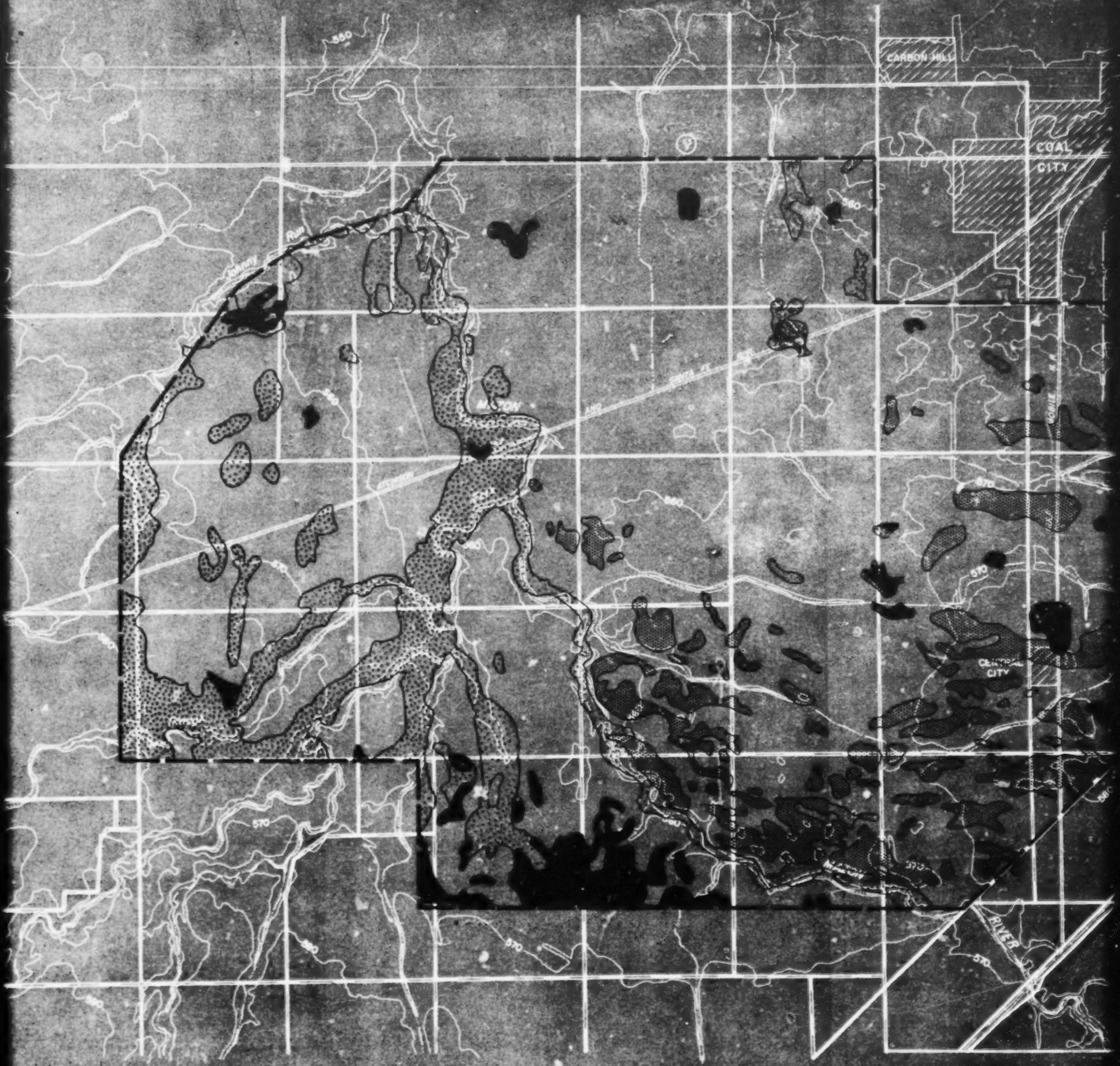
(c) Productivity is already high at the Coal City site, it has good topography and surface drainage is no problem, hence, any enhancement from a sludge disposal scheme appears to be slight. Large acreages of the sandy soils at the St. Anne site are sub-irrigated with increases in crop productivity. This means that a sludge disposal system would not greatly benefit much of the area. The droughty sandy areas could be improved by the addition of sludge, but much of the sand is in dune areas where a system of sludge disposal would be difficult to develop.

The Essex site, while it has poorly drained areas, does not have the potential for sub-irrigation that is present at the St. Anne site. The wet soil areas are scattered about

in an undulating topography that would be greatly benefited by artificial drainage and land leveling. Productivity is generally low in the area.

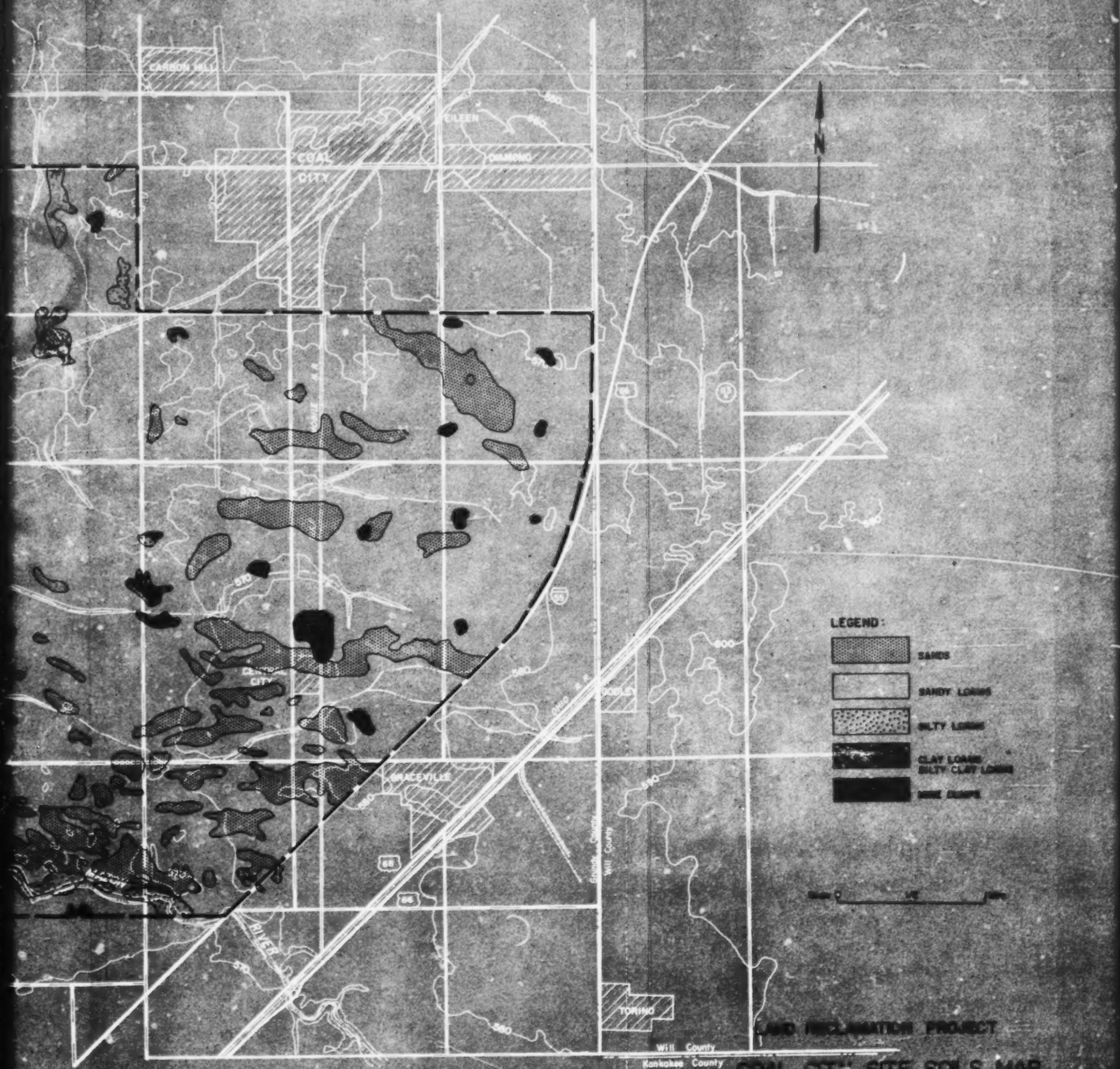
It appears that if the potential for sub-irrigation in the St. Anne area is developed, that its productivity will surpass that of the Essex area and that development of a sludge disposal system would not be of great significance in increasing productivity.

The Essex site offers the best opportunity for improving soil and land productivity.



A

EXHIBIT C-1



LEGEND:

- SANDS
- SANDY LOAMS
- SILTY LOAMS
- CLAY LOAMS
SILTY CLAY LOAMS
- MIKE SPOILS

LAND RECLAMATION PROJECT
COAL CITY SITE SOILS MAP

B



A
HARZA ENGINEERING COMPANY DWG. NO. 481P23 OCTOBER 1967



- LEGEND
- SANDS
 - SANDY LOAMS
 - SILTY LOAMS
 - CLAY LOAMS
SILTY CLAY LOAMS
 - MUCK

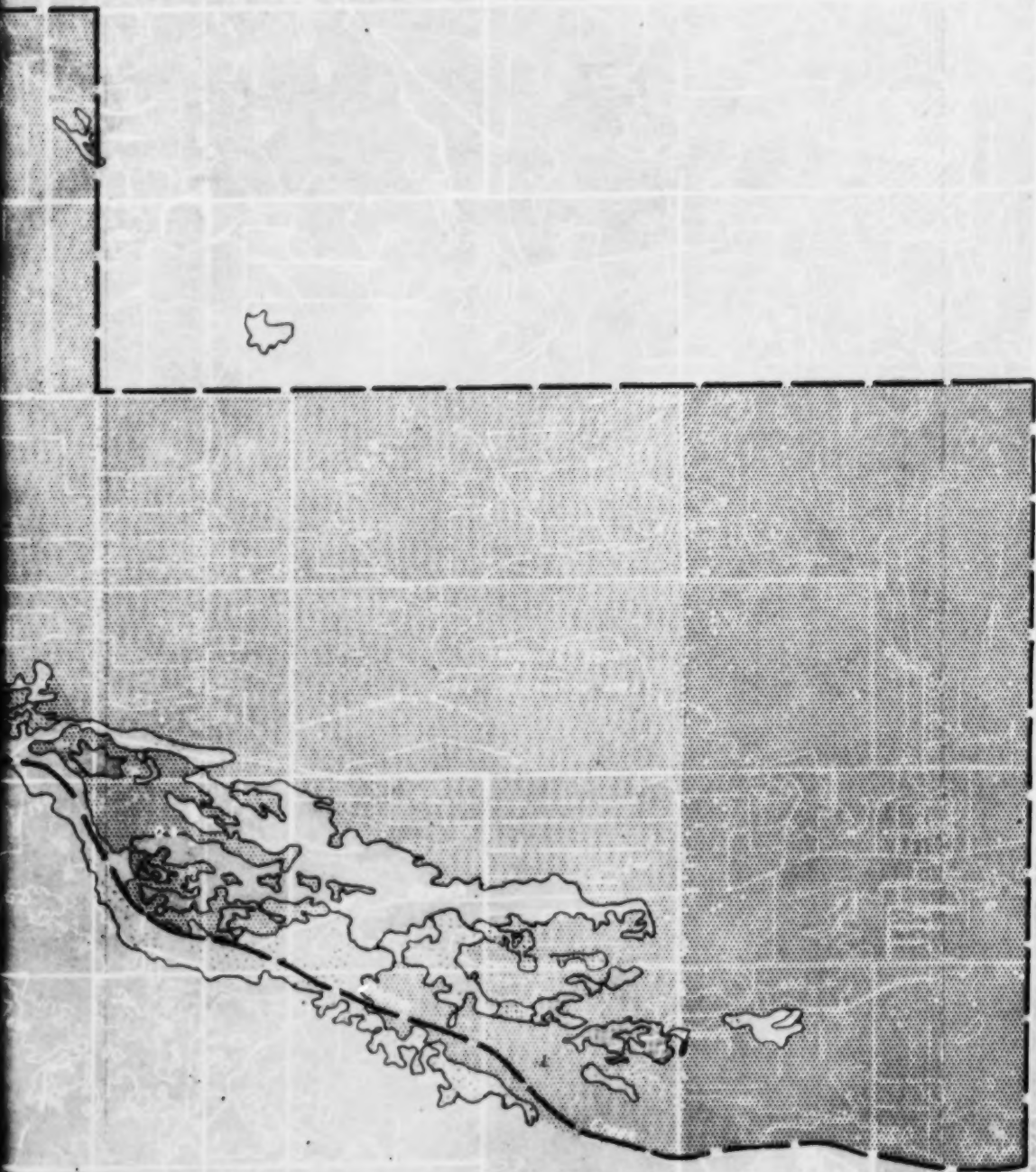
Scale 0 2000 4000 Feet

LAND RECLAMATION PROJECT
ESSEX SITE SOILS MAP

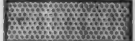
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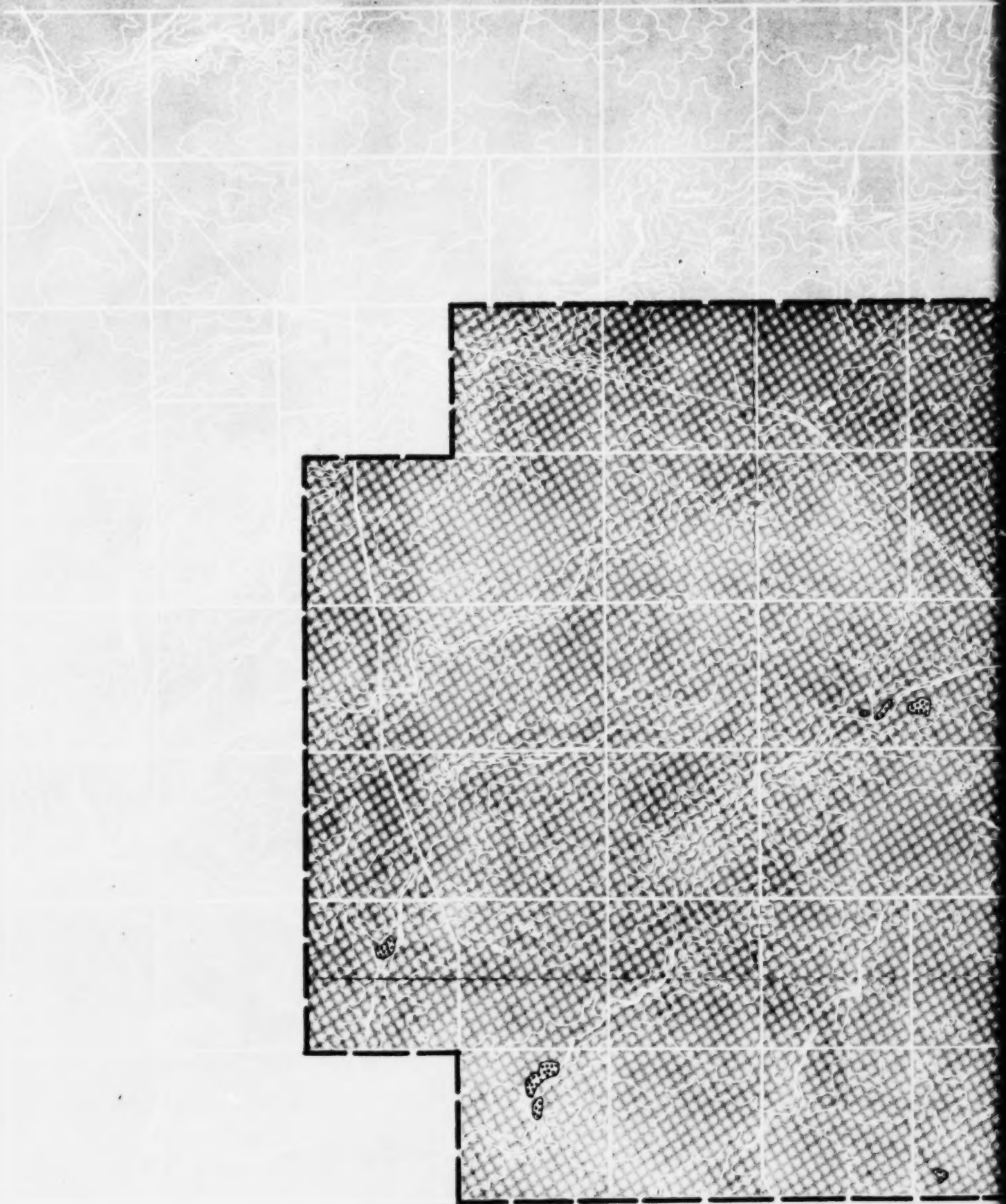
LEGEND:

- | | |
|---|---------------------------------|
|  | SANDS |
|  | SANDY LOAMS |
|  | SILTY LOAMS, LOAMS |
|  | CLAY LOAMS,
SILTY CLAY LOAMS |

Scale 0 1000 2000 3000 4000 5000 Feet

LAND RECLAMATION PROJECT
ST. ANNE SITE SOILS MAP

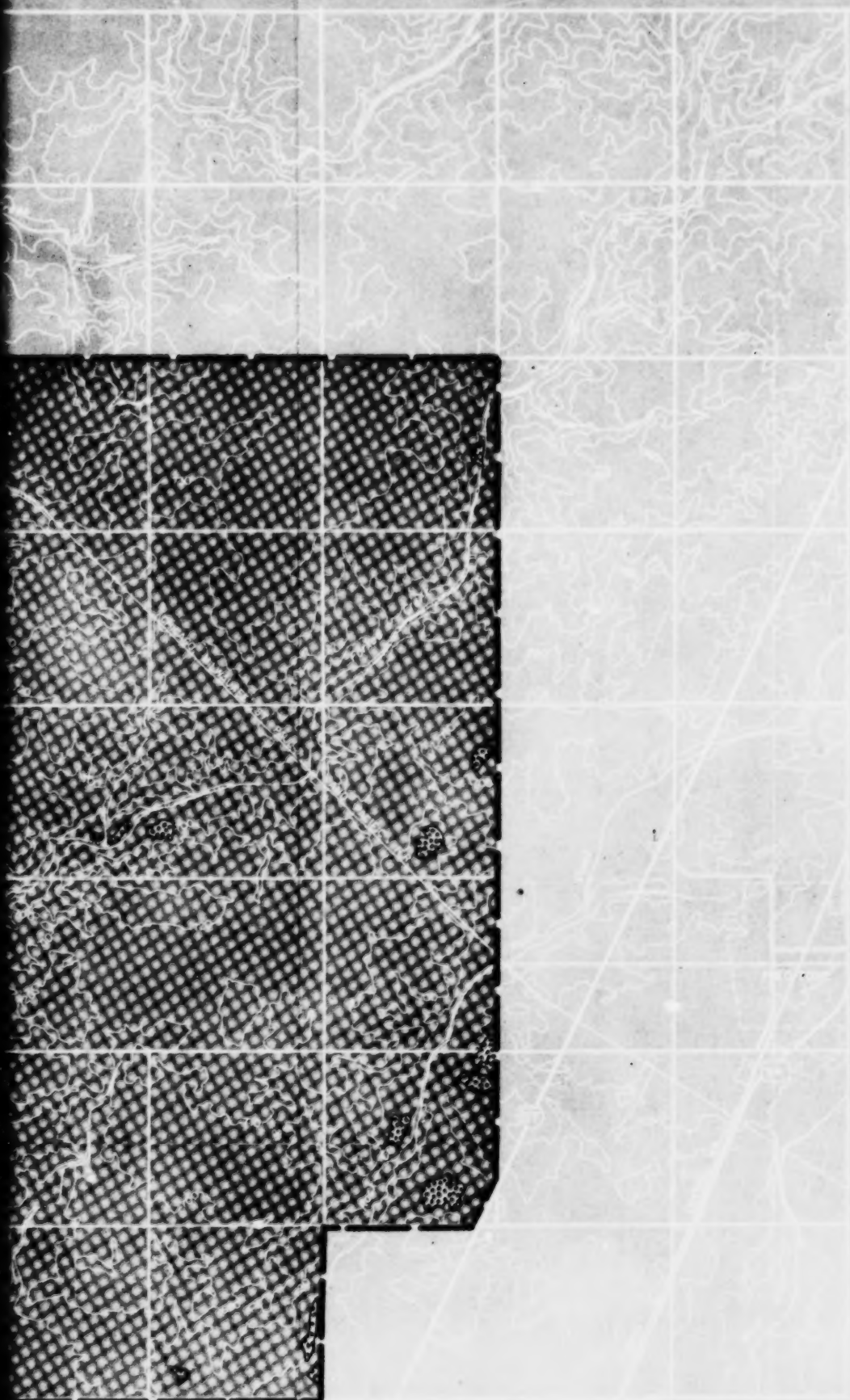
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HARZA ENGINEERING COMPANY DWG. NO. 422P24 OCTOBER 1967

EXHIBIT C-4



LEGEND



SILTY LOAMS, LOAMS



CLAY LOAMS,
SILTY CLAY LOAMS

Scale 0 1000 2000 3000 4000 5000 Feet

LAND RECLAMATION PROJECT

ANDRES SITE SOILS MAP

13

HEAVY METAL CONCENTRATION IN SANITARY DISTRICT
DIGESTED SLUDGE

ppm on dry basis

<u>Location</u>	<u>Date</u>	<u>Zinc</u>	<u>Copper</u>	<u>Chromium</u>	<u>Nickel</u>	<u>Lead</u>	<u>Cadmium</u>
Calumet Digester	6-67	2600	1130	750	120	180	81
Southwest Digester	6-67	6570	1630	3040	450	650	290
Lagoon - Bottom	6-67	5320	2190	2720	370	630	370
Calumet Digester ^{1/}	7-66	3340	1160	1670	trace	3250	360
Southwest Digester ^{1/}	7-66	6500	2050	3600	440	840	490
Calumet Digester ^{1/}	7-66	3100	820	1680	70	3100	34
Southwest Digester ^{1/}	7-66	6700	2200	3500	540	860	410

Assumed concentration
on dry basis, ppm

1/ Calculated from values shown in Exhibit A-1

PROJECTED EFFECTS OF HEAVY METALS

<u>Element</u>	<u>Total Content in Soil</u> ^{1/}		<u>Annual Addition</u> ^{2/}		<u>Contents at 50 Years</u> ^{3/}		<u>Lower Limit of Toxicity to Plants ppm(available)</u>
	<u>Range</u> ppm	<u>Typical</u> ppm	<u>lbs/A</u>	<u>from Sludge</u> ppm	<u>Total</u> ppm	<u>Available</u> ppm	
Zinc	10-300	100	200	100	5000	5	5
Copper	10-200	40	80	40	2000	2.0	2
Chromium	5-1000	-	120	60	3000	3	5
Nickel	5-500	100	16	8	400	0.5	2
Lead	2-200	20	60	30	1500	1.5	10

1/ Data from "Diagnostic Criteria for Plants and Soils" edited by H.D. Chapman, University of California, Division of Agricultural Sciences, 1966.

2/ A 20-ton per acre per year rate is assumed. Also, it is assumed that dry sludge contains 5000 ppm Zn, 1500 ppm Cu, 3000 ppm Cr, 400 ppm Ni, and 1500 ppm Pb. (See Table 1).

3/ It is assumed that about 0.1% of the total is in a form available to plants at a pH of 7; availability increases as pH is decreased.

ZINC AND COPPER CONCENTRATIONS IN SOILS AT
THE BERLIN AND PARIS SEWAGE FARMS

<u>Soil Sample Number</u>	<u>Extracted with 10% HCl</u>		<u>Extracted with boiling H₂O ^{1/}</u>	
	<u>Copper ppm</u>	<u>Zinc ppm</u>	<u>Copper ppm</u>	<u>Zinc ppm</u>
	<u>Berlin</u>		<u>Paris</u>	
1	63	102	4.43	1.44
1a ^{2/}	260	290	14.8	3.32
2	138	221	14.47	8.52
2a	372	510	25.27	16.83
3	138	198	8.86	6.39
3a	683	776	28.94	28.59
4	134	267	7.08	9.58
4a	718	860	11.23	27.73
Average: Healthy	118	197	8.71	6.48
Unhealthy	508	609	20.06	19.12
5	91	305	3.5	1.92
5a	156	500	8.5	4.64
6	128	383	7.0	1.92
6a	160	577	6.0	5.44
7	165	400	12.0	4.58
7a	304	850	15.5	6.88
8	144	455	11.5	5.28
8a	545	2200	14.8	24.96
Average: Healthy	132	386	8.5	3.43
Unhealthy	291	1032	11.2	10.48

^{1/} Water extracted copper and zinc are readily available to plants.

^{2/} Letter "a" denotes soil samples taken in areas of unhealthy plants.

SOILS PROPERTIES ^{a/}

Horizon Depth	Particle Size Distribution ^{b/}				Exchangeable Cations			Cation Exchange Capacity	Base Saturation	pH	Organic Carbon
	Gravel	Sand	Silt	Clay	Ca	Mg	K				

HAGENER LOAMY SAND												
(Coal City, Essex, St. Anne Sites)												
	in	%	%	%	%	me.	per 100 g		soil	%		%
A ₁	0-16	1.0	84.3	9.1	6.6	4.1	0.3	0.2	8.2	57	6.2	0.42
A ₃ -1...	16-26	1.0	84.1	9.4	6.5	2.6	0.3	0.1	5.8	53	5.8	0.19
A ₃ -2...	26-34	1.0	85.9	8.4	5.7	2.5	0.3	0.1	5.4	56	5.8	0.12
A ₃ -3...	34-80	4.0	93.1	3.1	3.8	1.7	0.2	0.1	3.3	64	5.8	0.01

ALVIN FINE SANDY LOAM												
(Coal City Site)												
A _p	0-6	0.0	67.0	27.7	5.3	2.9	1.8	0.1	7.5	64	6.8	.61
A ₂ -1...	6-11	0.0	65.4	29.2	5.4	1.2	0.9	0.1	5.3	40	5.8	.18
A ₂ -2...	11-16	0.0	64.8	28.0	7.2	1.7	0.7	0.1	5.3	45	5.4	.08
B ₁	16-20	0.0	65.5	22.9	11.6	3.2	1.2	0.1	8.7	52	5.3	.10
B ₂ -1...	20-27	0.0	67.7	15.8	16.5	3.9	2.6	0.2	12.8	54	5.0	.09
B ₂ -2...	27-35	0.0	75.1	9.5	15.4	4.0	3.7	0.1	13.0	61	5.0	.05
B ₂ -3...	35-44	0.0	77.1	9.8	13.1	3.2	3.2	0.2	10.6	62	4.8	.03
B ₃	44-50	0.0	77.8	10.7	11.5	2.7	2.9	0.2	10.2	57	4.8	.03
C.....	50-65	0.0	82.1	10.1	7.8	2.0	1.9	0.2	7.4	56	5.0	.07

ELLIOT SILT LOAM												
(Andres Site)												
A ₁ -1...	0-5	0.1	8.8	65.7	25.5	17.4	3.2	1.2	24.2	92	6.2	4.31
A ₁ -2...	5-10	0.1	8.5	64.5	27.0	16.0	2.6	.7	22.2	87	5.8	3.28
A ₃	10-14	0.2	7.9	61.7	30.4	14.6	2.3	.6	20.2	87	5.8	2.08
B ₂ -1...	14-19	0.4	8.3	53.8	37.9	13.4	3.2	.6	19.6	88	5.9	1.33
B ₂ -2...	19-24	1.2	9.4	46.3	44.3	12.9	4.4	.6	18.6	97	6.5	.88
B ₃	24-29	0.5	10.5	45.4	44.1	12.8	4.6	.5	18.4	98	7.0	.93
C.....	29-48	7.4	15.2	54.2	30.6		...	...		...	7.9	.57

ASHKUM SILTY CLAY LOAM												
(Andres Site)												
A _p	0-6	T ^c	7.7	52.7	39.6	28.7	10.1	.50	38.2	82	6.4	4.7
A ₁ -1...	6-8	T ^c	7.9	51.0	41.1	29.9	10.3	.50	37.5	83	6.5	4.1
A ₁ -2...	8-11	T	9.0	48.0	42.1	25.0	9.8	.40	31.6	88	6.8	1.9
B ₁	11-16	T	9.2	49.7	41.1	20.6	8.4	.40	26.4	89	7.1	1.0
B ₂ -1...	16-21	T	7.3	52.9	39.8	17.8	7.8	.40	23.6	91	7.3	.6
B ₂ -2...	21-26	T	6.5	53.8	39.7	18.4	8.6	.40	23.5	93	7.3	.5
B ₃	26-32	T	14.5	48.5	37.0	14.2	6.4	.30	18.0	94	7.5	.6
HC.....	32-50	T	15.2	48.7	36.1	 ^{d/}	...			...	7.9	.7

a/ Taken from "Will County Soils," Soil Rpt. 80, Illinois, Agr. Exp. Sta., 1962

b/ Gravel is material > 2.0 mm; sand, 2.0-.05mm; silt, .05-.002mm; clay < .002mm. Percentages for gravel are based on entire sample; those for other particle sizes are based on material < 2.0 mm.

c/ T = Trace

d/ Not determined.

EFFECTS OF SLUDGE APPLICATION ON SOIL

Physical Effects

Property			
(1)	<u>Soil Structure</u>	<u>Sand Soils</u>	<u>Silty Clay Loam Soils</u>
	Degree and type of aggregation	Slight improvement owing to some aggregation of particles from cementation by organic compounds.	Moderate improvement due to aggregation of clay particles makes soil more friable, less cloddy. Stability of aggregates will be greater.
(2)	<u>Infiltration Rate</u>		
	Penetration of water into surface soil	Decreased rate owing to addition of fine particles and grease from sludge.	No change or increase owing to improved aggregation.
(3)	<u>Permeability</u>		
	Movement of water within soil	Decreases permeability if sludge mixed into soil - if placed as a layer may cause temporary perching of water.	Increases permeability if sludge mixed into soil.
(4)	<u>Maximum Retentive Capacity</u> - Percent H_2O at saturation	Increases substantially, e.g. 30% to 50%	No change or may decrease slightly.
(5)	<u>Available Moisture Capacity</u> - Moisture available to plants	Increases somewhat - field capacity (1/3 atm.) is increased substantially but wilting coeff. (15 atm.) increases proportionately so net gain in available moisture is not great.	No significant change - or slight increase.
(6)	<u>Free Water</u>		
	Superfluous to plant needs.	No effects if under-drainage is provided.	May cause brief periods of water logging even though under-drainage is provided. Dependent on loading rate of the wet sludge and timing of application.
(7)	<u>Trafficability</u>		
	Vehicular traffic on field surface.	No change or delay due to sludge application.	May delay traffic over field for 2-3 days depending on rate of sludge application and natural rainfall.
(8)	<u>Susceptibility to Wind and Water Erosion</u>		
	Assuming no cover crop.	No appreciable change or may be somewhat less susceptible to wind erosion, particularly if sludge applications are frequent enough to keep surface moist.	May lessen water erosion by increasing infiltration rate.
(9)	<u>Soil Texture</u>		
		It is assumed that a substantial part of the insoluble ash in sludge is of silt and clay size (< 50 microns). Therefore, it is expected that an admixture of 10T. sludge (or about 2-3tons ash) per acre per year will gradually produce a finer textured soil. For example, a loamy sand may be changed to a sandy loam.	The effect of sludge on silty clay loam soils would tend to coarsen the texture somewhat.

EFFECTS OF SLUDGE APPLICATION ON SOIL

EFFECTS OF SLUDGE APPLICATION ON SOIL

Chemical Effects

<u>Property</u>	<u>Sand Soils</u>	<u>Silty Clay Loam Soils</u>
(1) <u>Cation Exchange Capacity (CEC)</u> (Also buffering capacity or resistance to pH change)	Should increase substantially, sandy soils have CEC of about 5 meq/100g., with sludge it might be increased to 10 to 15 assuming organics in sludge are comparable to soil humus which has a CEC of about 150.	May increase somewhat - clay component in these soils and native organic matter have CEC's of from 20-40 meq./100 g.
(2) <u>Exchangeable Cations</u>	The normal order of abundance of exchangeable cations held on exchange sites of Illinois soils is $Ca > Mg > K > Na$. This is determined by factors other than soil texture. The order of abundance in the sludge is the same although the proportions may be quite different than in soils. Assuming that these elements are in ionic form (readily dissociated salts) it does not appear that sludge applications to soils will upset the balance of exchangeable cations except that occasionally Na may surpass K in abundance. This probably will not have any serious side effects, i. e., Na should not become so abundant on the exchange sites of clay particles as to cause dispersion ("puddling"), also, K can be readily applied as a commercial fertilizer should it become a limiting plant nutrient.	
(3) pH	Owing to the high pH of sludge (7.0 - 7.5) and the low buffering capacity of sands the pH should be increased to near neutrality in a short period of time.	Sludge will increase pH but the change will be more gradual than in sands; also greater amounts of sludge would be required to cause changes in pH comparable to those in sands.
(4) <u>Ability to Adsorb Heavy Metals (Cu, Zn, Ni, Pb, Cr, Mo,</u>	Sands in original condition have virtually no capacity to adsorb heavy metals. Any adsorption capacity for heavy metals would be associated with the sludge itself. It is not known at this time to what extent this capacity is saturated with respect to the heavy metals already present in the sludge. Research is needed to determine this.	Soils with fair amounts of silicate clays (montmorillonite, vermiculite, and illite) have a fairly high capacity to adsorb heavy metals. However, little is known about the long term effects, e.g. Is the adsorption capacity saturated with respect to Cu, Zn, etc., in a few years, in a hundred years of continued sludge application?
(5) <u>Ability to Adsorb Ammonium Ion</u>	Sands have no ability to adsorb ammonium ion. The addition of sludge will increase the adsorption capability of the soil-sludge mixture.	It is reported that as much as 50% of the total N present in certain illite-containing soils has been found to be in the "fixed" ammonia form. In this fixed form, the nitrogen is not subject to rapid oxidation, although in time it may become available.
(6) <u>Ability to Adsorb Phosphates</u>	Sands have little or no ability to adsorb phosphates. Adsorption of phosphates will be related to organic matter content. From the standpoint of Phosphate-fertility the addition of sludge should therefore be quite beneficial on sandy soils, particularly since Ca is also added and the pH of the sludge is near neutral to slightly alkaline.	As in the case of sandy soils much of the soil phosphorous in silty clay loam soils is associated with the organic matter. Although the anion adsorption properties of the chief clay minerals present in Illinois soils are low some adsorption of this type will undoubtedly take place. Also, if soil pH is acid, fixation of phosphorus by Fe and Al compounds will take place (most of these compounds occur in the clay fraction); at alkaline pH values phosphates will be precipitated as Ca-phosphate.

EFFECTS OF SLUDGE APPLICATION ON SOIL

Bacteriological Effects

<u>Property</u>	<u>Sand Soils</u>	<u>Silty Clay Loam Soils</u>
(1) <u>Bacteria</u> <u>Population</u>	Owing to the droughty nature of sand soils organic residues are quickly oxidized. Hence, existing populations of microorganisms are generally quite low. The addition of the organics in the sludge to sand soils may increase existing populations as well as introduce new colonies and species. California data ^{1/} suggest that a 10 to 50 fold increase in bacterial populations in sandy soils from sludge application may be expected. A pH increase to about neutral due to sludge application may further stimulate bacteria growth.	Good agricultural soils with moderate moisture holding capacities and fairly high organic matter contents usually carry a great number of microorganisms. Populations introduced with the sludge and the addition of organic materials in the sludge may or may not increase bacteria populations. The possibility exists that the competition between various kinds of microorganisms may depress total populations; also certain inorganic substances, e.g., copper salts may act as bactericides. It is likely that sludge applied to the silty clay loam prairie soils of Illinois will not be beneficial to soil bacteria either in kinds or numbers.

^{1/} Report on Continued Study of Waste Water Reclamation and Utilization. State Water Pollution Control Board, Sacramento, California, Publication No. 15, 1956.

SOIL PROPERTIES

Soil Property	Coal City Site	Essex Site	St. Anne Site	Andres Site	Tinley Park Site
A. Soil Texture					
	Sands				
	Sandy loams	7% of total area	60% of total area	0% of total area	0%
	Silt loams - loams	79% of total area	5% of total area	0% of total area	0%
B. Soil Productivity ^{a/}					
	Sands	57 bu/A	54 bu/A	-	-
	Sandy loams	83 "	74 "	-	-
	Silt loams - loams	97 "	94 "	92 bu/A	92 bu/A
C. Slope Gradient					
	0 - 3%	83 "	74 "	80	80
	3 - 5%	97 "	94 "	80	80
	5 - 8%	83 "	74 "	87 bu/A	87 bu/A
D. Soil Infiltration (and Permeability Rates)					
	Rapid (5-10 in/hr)	81 bu/A	64 bu/A	87 bu/A	87 bu/A
	Mod. rapid (2.5-5 in/hr.)	80% of total area	80% of total area	30% of total area	90% of total area
	Mod. Slow (.2 - .8 ")	15% of total area	10% of total area	50% of total area	10% of total area
E. ^{b/}					
	1. Moisture Retention	50%	80%	30%	90%
	2. Moisture Availability	30%	10%	50%	10%
	3. Runoff Hazard	18%	5%	15%	0%
F. Corn Yields - 10 year averages with average management. Based on Soil Conservation Service and Illinois Agricultural Exp. Sta. data.					
	4. Absorption Capacity	2%	5%	5%	0%
	5. Natural Fertility	42%	60%	0	0
	6. Productivity increase with sludge	46.5 (26.5)	5	0	0
G. Erosion hazard - wind					
	7. Productivity increase with sludge plus irrigation	11 (20)	11 (5)	60 (100)	(100%)
	8. Erosion hazard - wind	0.5 (11.5)	24 (35)	40 (100)	(90%)
	9. Erosion hazard - water	1	1	4	4

EXHIBIT C-10

^{a/} Corn yields - 10 year averages with average management. Based on Soil Conservation Service and Illinois Agricultural Exp. Sta. data.
^{b/} These characteristics are estimated and rated on a four point scale (low = 1, High = 4).

Appendix D

AGRICULTURE DEVELOPMENT

Cropping Pattern

Introduction

A study by the University of Illinois to be completed at a later date will recommend crops to be grown on the reclaimed lands. However, until these recommendations are available an interim cropping pattern is required for the agriculture studies.

Determination of a cropping pattern for an agriculture project requires consideration of many factors including climate, soils, markets, transportation facilities, present practices, and general economic and social conditions of the area. With the addition of sludge, other factors, such as nutrient utilization and removal and requirements for sludge application, enter into determination of a cropping pattern.

Normal Considerations

In the Kankakee area, the climate and soils are well suited to the crops presently grown. The markets and transportation facilities are more than adequate to handle present crop production. Table D-1 shows the present cropping distribution in Grundy, Kankakee, Iroquois and Will Counties.

Nutrient Utilization

One of the main purposes for cropping with the sludge disposal operation is to remove as many plant nutrients from the soil as

Table D-1

CROPPING PATTERNSPresent Cropping Practices^{1/}
(Percent of Cropped Areas)

<u>Crop</u>	<u>County</u>			
	<u>Grundy</u>	<u>Kankakee</u>	<u>Iroquois</u>	<u>Will</u>
Corn	51.4	49.3	47.4	46.2
Soybeans	30.9	32.9	32.8	28.6
Wheat	1.8	7.1	5.3	7.1
Oats	8.5	5.2	6.7	8.2
Alfalfa	5.3	3.6	4.2	6.2
Vegetables (including Popcorn & Potatoes)	0.5	0.3	1.4	1.4

Projected Cropping Pattern^{2/}
(Sandy Soil Sites)

<u>Crop</u>	<u>Percent of Net Area</u>
Corn	50.0
Soybeans	25.0
Spring Grains	10.0
Alfalfa	10.0
Grass (Reclamation area)	5.0

^{1/} Taken from the 1964 Agriculture Census for the counties listed.^{2/} Crops and percentages for which water requirements are computed.

possible. For this reason it is important that the crops grown require large amounts of nutrients. Nitrogen has been used as an indicator of the amount of nutrients removal. Crops such as corn, soybeans, and alfalfa require large amounts of nitrogen in which are extracted mainly from the soil. Normally, soybeans and alfalfa utilize some nitrogen from the atmosphere, but with excess nitrogen available in the soil this is less likely to occur.

Estimates of the amount of nitrogen removed from the soil by crops are: ^{1/}

Corn	- 140 bushels of grain - 140 lbs nitrogen
Soybeans	- 35 bushels of grain - 135 lbs nitrogen
Alfalfa	- 3 tons of dry-weight - 170 lbs nitrogen

Sludge Application

Sludge delivery to the area will be on a 24 hour basis, 365 days per year. Some crop areas must, therefore, accept the sludge any time of the year. On crops such as corn, soybeans and spring grains, sludge application before and during planting and harvesting would not be possible. Areas of grass or alfalfa will be required to take the sludge during these periods and during periods of rainfall.

Crops Selected

To disrupt existing markets, transportation facilities and general economic conditions of the area as little as possible the cropping pattern selected is similar to present crops grown. The projected crop percentages with sludge application are shown on Table D-1.

^{1/} Soil Report 74, University of Illinois, 1951, measured from crops grown in central and northern Illinois.

Corn, soybeans, and alfalfa crops are high nitrogen utilizers. Spring grains would not remove large amounts of nitrogen but would be used to start the grass and alfalfa. Grass will utilize large amounts of nitrogen, but with high sludge loadings harvesting will be difficult. Also, a market may not be available for the grass. If grass can be economically harvested and marketed, much of the alfalfa should be replaced with grass to allow greater sludge loadings.

In determining the sludge application schedule for the selected cropping pattern, a disposal rate of 1,060 tons of dry solids per day and a net cropped area of 19,400 acres was used. Table D-2 shows the monthly sludge application schedule for sandy soil. This application schedule is based on a loading rate of 10 tons per acre per year on all crops except grass and 210 tons per acre per year on grass (reclamation areas).

On the heavy soil, it is uneconomical to level the land to allow surface application of the sludge on growing crops. For this reason, the cropping pattern on heavy soil is modified to allow application of sludge during non-growing periods for all crops except grass and alfalfa. Table D-3 shows the sludge application schedule necessary to handle the required sludge volume using a cropping pattern of about 33% corn, 22% soybeans, 10% spring grains, 14% alfalfa and 21% grass. This schedule assumes an annual rate of 10 tons per acre on corn and soybeans, 20 tons per acre on spring grains and alfalfa and about 45 tons per acre on grass.

Table D-2

SLUDGE APPLICATION SCHEDULE
SANDY SOIL SITES

<u>Month</u>	<u>Crop</u>	<u>Days of Application</u> ^{1/}
January	Corn	16
	Grass	15
February	Soybeans	16
	Grass	12
March	Soybeans	10
	Grass	21
April	Alfalfa	10
	Grass	20
May	Spring grains	10
	Grass	21
June	Corn	15
	Grass	15
July	Corn	20
	Grass	11
August	Corn	21
	Grass	10
September	Spring grains	8
	Grass	22
October	Alfalfa	8
	Grass	23
November	Soybeans	20
	Grass	10
December	Corn	20
	Grass	11
		<u>365</u>

Totals: Corn 92 days, Soybeans 46 days, Spring Grains 18 days, Alfalfa 18 days, and Grass 191 days.

^{1/} Using a disposal rate of 1,060 tons of dry solids per day and a net cropped area at 19,400 acres.

Table D-3

SLUDGE APPLICATION SCHEDULE
HEAVY SOIL SITES

<u>Month</u>	<u>Crop</u>	<u>Days of Application</u> ^{1/}
January	Corn	20
	Grass	11
February	Corn	20
	Grass	8
March	Soybeans	20
	Grass	11
April	Alfalfa	20
	Grass	10
May	Alfalfa	10
	Grass	21
June	Alfalfa	10
	Grass	20
July	Alfalfa	10
	Grass	21
August	Spring Grains	16
	Grass	15
September	Spring Grains	20
	Grass	10
October	Alfalfa	20
	Grass	11
November	Soybeans	20
	Grass	10
December	Corn	20
	Grass	<u>11</u>
		365

Totals: Corn 60 days, Soybeans 40 days, Spring Grains 36 days, Alfalfa 50 days and Grass 179 days.

^{1/} Using a disposal rate of 1,060 tons of dry solids per day and a net Cropped area of 19,400 acres.

Need For Irrigation

Introduction

In the humid area of the United States, including the Kankakee area of Illinois, rainfall and soil moisture seldom are adequate to provide plants with all the water needed for optimum growth and production. Yield reductions due to water deficiency will vary depending on soil type and the growing season in which it occurs. For some crops, yield reductions are not great enough to justify supplemental irrigation.

Irrigation in humid areas is normally used to protect crops from drouth, increase yields and in some cases for frost protection. With the application of sludge, an additional use for irrigation, especially on sandy soil, will be to insure a high level of nutrient removal by the crops. In determining the need for irrigation, corn was used as a representative crop.

Nutrient Utilization

Nitrogen, phosphate, potash and heavy metal removals from a soil increase almost proportionately with increases in grain crop yields. Therefore, since supplemental irrigation water will increase growth and production, the amount of nutrients removed from the soil will also be increased. For example, a corn crop yielding 47 bushels of grain per acre utilizes about 65 pounds of nitrogen, whereas a crop that yields 188 bushels of grain utilizes more than 260 pounds of nitrogen ^{1/}. With the large amounts

^{1/} "Irrigation of Agriculture Lands," Agronomy Series No. 11, (1967), Chapter 24.

of nitrogen and heavy metals present in sludge loadings of ten to twenty tons per acre, consistent high yields will be very important to success of the operation.

Drouth Probability

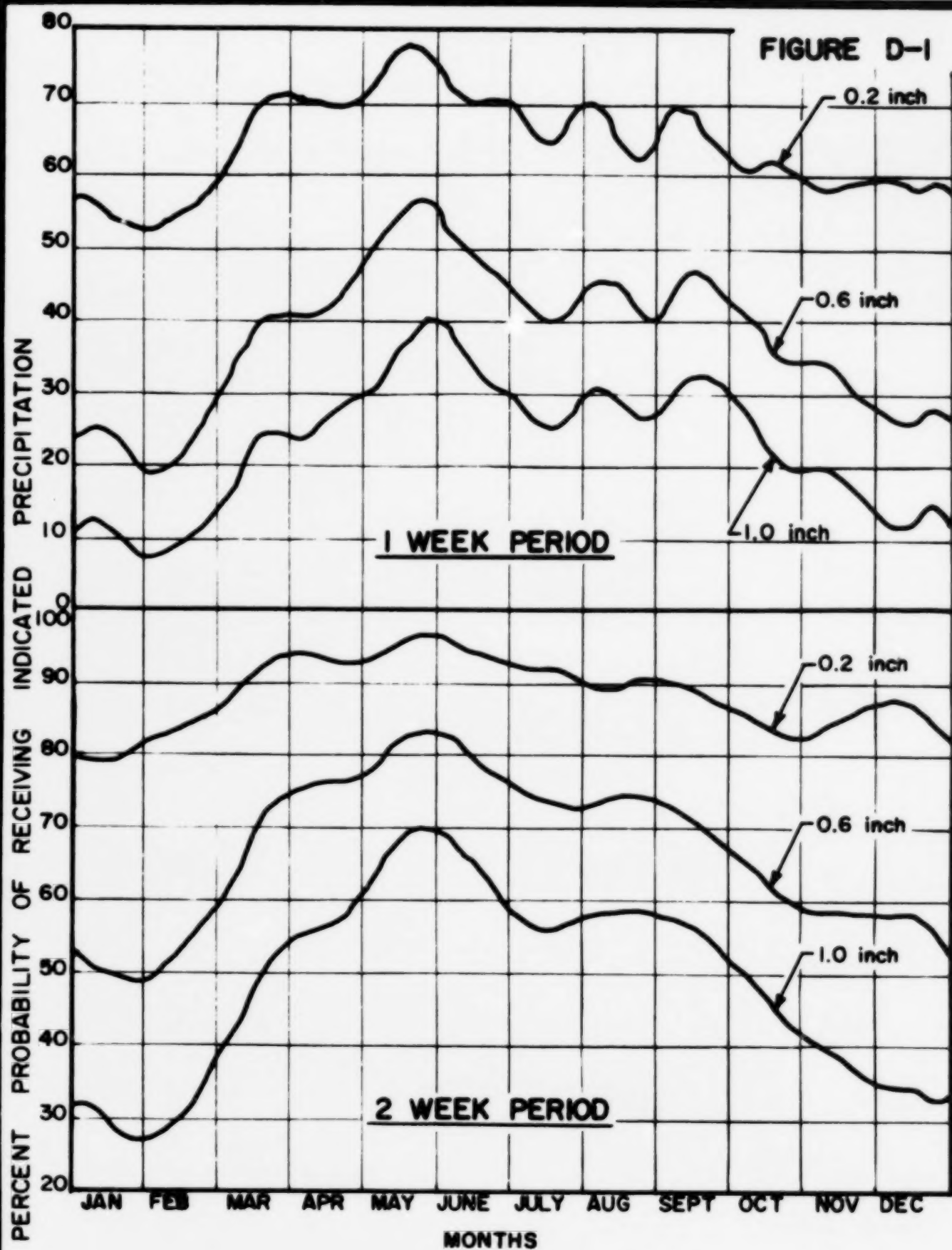
The possibility of a drouth of sufficient duration to reduce corn yields will depend on the probability of receiving substantial rainfall during critical periods and the moisture holding capacity of the soil. Figure D-1 shows the percent probability of receiving 0.2, 0.6, and 1.0 inch of rainfall during 1- and 2-week periods. These probabilities are based on Aurora College weather records, which are applicable to the Kankakee area. The moisture holding capacity of sandy and heavy soils, and the total moisture available to the crops are given in Table D-4.

Computations for corn (given later in Table D-11) show a peak consumptive use requirement of 0.32 inches of water per day. With this peak requirement and assuming 75 percent of the soil moisture is available to the crop, corn can go six days without additional moisture on sandy soil and 14 days on heavy soil. Longer periods without rainfall or supplemental water will result in yield reduction. The amount of yield reduction will depend on the length of the drouth and the crop growth stage at which the drouth occurs.

The probability of receiving a one-inch rainfall during July and August for a one-week period is about 30 percent and for a two-week period 60 percent.

Yields Expected

Corn generally tolerates appreciable moisture stress except during the growth period, which extends from tassel emergence to completion



Percent chance of receiving 0.2, 0.6, and 1.0 inch of rainfall during 1- and 2-week periods. Solid lines are smoothed 3-period averages. Based on records of Aurora College weather station.

Table D-4

SOIL MOISTURE

<u>Soil Type</u>		<u>Available Moisture Holding Capacity ^{1/}</u>	
Sands and Sandy Loams (Sandy Soil)		1.00	
Silt and Clay Loams (Heavy Soil)		2.40	

<u>Crop</u>	<u>Root Zone Depth ^{2/}</u> (inches)	<u>Total Available Moisture in the Crop Root Zone</u>	
		<u>Sandy Soil</u> (inches)	<u>Heavy Soil</u> (inches)
Corn	30	2.50	6.00
Soybeans	30	2.50	6.00
Spring Grains	24	2.00	4.80
Alfalfa	48	4.00	9.60
Grass	24	2.00	4.80

1/ Average value taken from the U.S.D.A. Soil Conservation Service Irrigation Guide for Illinois.

2/ The soil depth explored by most roots in taking up moisture-not the full root depth of the plant.

of pollination. Significant grain yield reductions result from early season stress only if it is prolonged or severe enough to cause severe wilting. However, due to sparseness of the initial root system prior to development of the secondary system, such wilting in early growth stages may occur when appreciable available soil water remains. In contrast, even moderate stress that results in significant wilting during the tasseling, silking, and pollination periods may reduce grain yield greatly. Stress adequate to desiccate the lower or the tender top leaves during this interval may cut grain yield in half. Appreciable stress can be tolerated during grain formation so long as firing of the leaves is avoided. Very high stress with significant firing of the leaves has little effect on grain yield during the maturing period ^{1/}.

In the Kankakee area the period of tasseling, silking, and pollination occurs about the last two weeks of July and the first two weeks of August. Using the estimated one inch rainfall probabilities, this means that on sandy soil, corn yields may be reduced by 50 percent at least 40 percent of the time. However, on heavy soil little or no reduction in yield would occur in this same period.

The corn yield estimates for conditions with and without irrigation assume sludge application and good management. Using the above computations and present yield data, the non-irrigated average corn yields were estimated at 80 bushels per acre on sandy soil and 120 bushels per acre on heavy soil. The irrigated average corn yield per acre on both the sandy and heavy soils is estimated at 140 bushels.

^{1/} "Irrigation of Agriculture Lands," Agronomy Series No. 11 (1967), Chapter 32.

Irrigation Costs and Benefits

In order to determine an indication of the economic return from irrigation, costs and returns were computed for corn. Table D-5 shows the results of these computations. Procedures used to determine farm production costs and returns are described in Appendix H.

Other Factors

An important factor which could change the estimate of agricultural production and return is an increase in available soil-moisture holding capacity caused by sludge application. Literature ^{1/} indicates this increase may be as high as 50 percent with high load applications. On this basis, the available soil-moisture holding capacity of sandy soil would increase from about 1.0 to 1.5 inches per foot. This is still not sufficient for consistently high crop yields without irrigation. The increase could optimistically be as high as 100 percent where loadings of four to five hundred tons per acre are applied. However, on sandy areas where this sludge loading will be applied, the available soil-moisture holding capacity is presently only about 0.75 inches per foot.

On heavy soil, the danger of damage to the crop root system by excess water is an important consideration. Because of low infiltration rates and permeability, the drainage system may be unable to

^{1/} "Continued Study of Water Reclamation and Utilization", California State Water Pollution Control Board, Publication No. 15, 1956.

Table D-5

IRRIGATION COSTS AND BENEFITS FOR CORN

(Per Acre)

Annual Costs

Yield levels, bushels per acre	80 Sandy Soil w/o Irrig.	120 Heavy Soil w/o Irrig.	140 Sandy & Heavy Soil with Irrig.
Labor and Management	\$ 16.00	\$ 24.00	\$ 28.00
Machinery and Power	13.75	16.75	18.25
Fertilizers ^{1/}	6.00	8.00	10.00
Seed and Crop Expense	4.20	8.20	10.20
Storage Costs	4.50	5.20	5.55
Interest on Stored Grain	2.35	2.95	3.05
General Farm Expense	4.30	4.30	4.30
Real Estate Taxes	4.00	8.00	10.00
Irrigation Costs ^{2/}			22.00
Total Costs	\$ 55.10	\$ 77.40	\$111.35

Annual Returns

Gross Return (at \$1.25/bushel)	\$100.00	\$150.00	\$175.00
Net Return	44.90	72.60	63.65

Benefit to Cost Ratio ComparisonsSandy Soil Irrigation Benefit Cost Ratio = $75/56.25 = 1.33$ Heavy Soil Irrigation Benefit Cost Ratio = $25/33.95 = 0.74$ ^{1/}Includes cost of additional fertilizer only with no cost for sludge used.^{2/}Includes \$14 for investment amortization, \$5 for pump and equipment maintenance and replacements, and \$3 for labor requirements.

remove excess water rapidly enough when a heavy rain occurs immediately after irrigation. Therefore, yields on heavy soils, may be reduced more by too much than by too little water.

It is noted that the increase in moisture holding capacity of sandy soil will occur gradually as the sludge is applied. But it would take at least 20 years to reach levels sufficient to eliminate irrigation and in actual practice this may never occur. In any case, investments for irrigation could be amortized before the need for irrigation on sandy soils would be completely eliminated.

Conclusions

Of particular importance to the use of sludge for agricultural production is the utilization of nitrogen. On sandy soil without irrigation only 80 pounds of nitrogen per acre year would be removed compared to 140 pounds with irrigation, representing an increase of about 75 percent. On heavy soils with irrigation the use of nitrogen would amount to 140 pounds per acre annually compared to 120 pounds without irrigation, representing an increase of only about 17 percent.

It was concluded from these studies that on heavy soil areas irrigation would not be justified due to lower net return. This results from higher production costs and reduced cropping intensities.

The conclusion for sandy soil is that irrigation would not only be justified but would be necessary for optimum nitrogen removal and to avoid frequent crop failures.

Water Requirements

Introduction

Water requirements for irrigation include (a) water beneficially consumed as transpiration by the growing crops and evaporated from the land surface of the field (consumptive use), (b) non-beneficial uses and losses including surface runoff and deep percolation (field losses) and, (c) water lost in conveyance from the source to the field (conveyance losses).

In this study, the amount of supplemental water required for irrigation of crops on sandy soil has been computed.

Consumptive Use

In the Kankakee area, where few consumptive use measurements are available, the consumptive water requirement of crops can be estimated from climatological data using an empirical method developed for this purpose. For this study the Blaney-Criddle method, as modified by the U.S.D.A. Soil Conservation Service, has been used to estimate the crop water requirements.

Blaney-Criddle Formula - The Blaney-Criddle formula is expressed by $u = k \times f$ where,

u = Monthly consumptive use of crops in inches

k = Empirical consumptive use crop coefficient for a month (varies by crops)

f = Monthly consumptive use factor

$f = \frac{t \times p}{100}$ where,

t = Mean monthly air temperature in degrees Fahrenheit

p = Monthly percentage of daytime hours of the year

The Soil Conservation Service made the following modifications:

$$k = k_t \times k_c \text{ where,}$$

k_t = A climatic coefficient related to the mean air temperature (t)

$$k_t = 0.0173t - 0.314$$

k_c = A coefficient reflecting the growth stage of the crop.

Table D-6 shows the mean temperature and daytime hours used for the computation of the consumptive use factor. Table D-7 shows the climatic coefficient and the crop growth stage coefficient used for the computation of the consumptive use coefficient.

Table D-7 also shows the computed consumptive use requirement for each crop in the projected cropping pattern.

Rainfall Dependability

Since monthly rainfall in the Kankakee area will vary from year to year, the amount of water to be provided by irrigation must be sufficient to supplement the effective rainfall in meeting crop needs. This required a study of rainfall dependability on a probability basis, the probability used being an economic consideration. A growing season rainfall amount which could be expected to be equalled (or exceeded) eight years out of ten was used (16.90). To obtain adjusted 80 percent probability monthly values, the actual mean monthly rainfall was multiplied by the ratio of the 80 percent probable growing season rainfall to the average growing season rainfall ($16.90 \div 20.76 = 0.82$). These adjusted monthly rainfall values are shown in Table D-6.

Effective Rainfall

Under normal rainfall conditions, not all the precipitation that falls on the land will be stored in the soil or used consumptively by the

Table D-6

MONTHLY RAINFALL, TEMPERATURE AND CONSUMPTIVE USE FACTORS

<u>Month</u>	<u>Mean Rainfall^{1/} inches</u>	<u>Rainfall 8 out of 10 years^{2/} inches</u>
April	3.67	2.99
May	3.86	3.14
June	3.87	3.15
July	3.14	2.56
August	3.32	2.70
September	<u>2.90</u>	<u>2.36</u>
Growing Season Total	20.76	16.90

<u>Month</u>	<u>Mean Temperature^{1/} (t) °F</u>	<u>Annual Daylight Hours^{3/} (p) Percent</u>	<u>Consumptive Use Factor^{4/} (f)</u>
April	50.2	8.95	4.49
May	60.9	10.05	6.12
June	70.9	10.15	7.20
July	75.1	10.36	7.78
August	73.2	9.60	7.02
September	66.3	8.42	5.58

^{1/} Mean Rainfall and Temperature from Illinois State Water Survey, Local Climatological data for Kankakee, Illinois for 50 year period 1917 through 1966.

^{2/} Rainfall expected to be equaled or exceeded in 8 years of each 10 year period for the growing season shown (April-September).

^{3/} Monthly percentage of daytime hours of the year for latitude 41° North.

^{4/} $f = \frac{txp}{100}$

Table D-7
CONSUMPTIVE USE

<u>Crop</u>	Consumptive ^{1/} Use Factor (f)	Climatic ^{2/} Coefficient ($kt = .0173t - .314$)	Growth ^{3/} Stage Coefficient (k_c)	Consumptive Use Coefficient ($k = k_t \times k_c$)	Consumptive Use ($u = k \times f$) (inches)
<u>Corn</u>					
May (1/2)	6.12	0.740	0.24	0.18	1.10
June	7.20	0.913	0.64	0.58	4.17
July	7.78	0.986	1.02	1.01	7.86
August	7.02	0.952	1.03	0.98	6.88
September (1/2)	5.58	0.833	0.45	0.37	2.07
<u>Soybeans</u>					
June	7.20	0.913	0.65	0.59	4.26
July	7.78	0.986	1.08	1.06	8.27
August	7.02	0.952	0.93	0.89	6.21
September (1/3)	5.58	0.833	0.23	0.19	1.07
<u>Spring Grains</u>					
April	4.49	0.554	0.50	0.28	1.24
May	6.12	0.740	1.04	0.77	4.72
June	7.20	0.913	1.24	1.13	8.15
July (1/2)	7.78	0.986	0.32	0.32	2.46
<u>Alfalfa</u>					
April	4.49	0.554	0.99	0.55	2.46
May	6.12	0.740	1.09	0.81	4.95
June	7.20	0.913	1.13	1.03	7.41
July	7.78	0.986	1.11	1.09	8.48
August	7.02	0.952	1.07	1.02	7.16
September	5.58	0.833	0.99	0.82	4.57
<u>Grass (Reclamation areas)</u>					
April	4.49	0.554	0.85	0.47	2.11
May	6.12	0.740	0.90	0.67	4.07
June	7.20	0.913	0.92	0.84	6.05
July	7.78	0.986	0.92	0.91	7.06
August	7.02	0.952	0.91	0.87	6.08
September	5.58	0.833	0.88	0.73	4.09

^{1/} From Table D-6

^{2/} Using temperatures listed in Table D-6

^{3/} Taken from Crop growth stage coefficient curves given in U.S.D.A. Technical Release No. 21.

plants. When precipitation is heavy, some water runs off the land, some forms surface pools and is evaporated, and some goes below the root zone as deep percolation. That part of the monthly precipitation which can be effectively used is related to the total rainfall, the rate of removal by evapotranspiration and the root zone storage capability of the soil. Table D-8 was used to relate monthly rainfall amounts and monthly consumptive use amounts to effective rainfall values.

Soil Moisture

In addition to effective rainfall, soil moisture carried over from winter precipitation is available to satisfy crop consumptive requirements. This soil moisture will satisfy part or, in some cases, all of the consumptive requirements not satisfied by summer rainfall. For this study, the winter precipitation was assumed sufficient to always bring the soil moisture in the root zone depth of the profile up to field capacity by spring. Table D-4 shows the amount of moisture available to various crops at the beginning of the growing season for sandy and clay soil in the Kankakee area.

Irrigation Water Requirements

Irrigation of sandy soil is assumed necessary because of its low moisture holding capacity. The application of sludge may increase the moisture holding capacity after a period of years which will lower the amount of irrigation water required. However, the moisture holding capacity will not increase to the point where irrigation is not required in an average year.

Table D-8

AVERAGE MONTHLY EFFECTIVE RAINFALL ^{1/}
AS RELATED TO
MEAN MONTHLY RAINFALL
AND
AVERAGE MONTHLY CONSUMPTIVE-USE

Monthly Mean Rainfall r_t Inches	Average Monthly Consumptive-Use, u , in Inches									
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Average Monthly Effective Rainfall, r_e , in Inches										
0.5	.20	.25	.30	.30	.30	.35	.40	.45	.50	.50
1.0	.55	.60	.65	.70	.70	.75	.80	.85	.95	1.00
2.0	1.00	1.25	1.35	1.55	1.55	1.55	1.60	1.70	1.85	2.00
3.0	1.00	1.85	1.95	2.10	2.20	2.30	2.40	2.55	2.70	2.90
4.0	1.00	2.00	2.55	2.70	2.90	2.95	3.15	3.30	3.50	3.80
5.0	1.00	2.00	3.00	3.25	3.50	3.60	3.85	4.05	4.30	4.60
6.0	1.00	2.00	3.00	3.80	4.10	4.25	4.50	4.80	5.10	5.40
7.0	1.00	2.00	3.00	4.00	4.60	4.80	5.05	5.40	5.70	6.05
8.0	1.00	2.00	3.00	4.00	5.00	5.30	5.60	5.90	6.20	
9.0	1.00	2.00	3.00	4.00	5.00	5.75	6.05	6.35		

^{1/} Based on 3-inch net depth of application. For other net depths of application, multiply by the factors shown below.

Net Depth of Application, Inches	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0	7.0	8.0
Factor	.77	.86	.93	.97	1.00	1.02	1.04	1.06	1.07	1.08

To determine the amount of irrigation water required, root zone depths from Table D-4 and effective rainfall derived from the 80 percent probability rainfall were used. This gives a water requirement for the second driest year out of ten. The irrigation water required for the various crops is given in Table D-9.

Field Irrigation Requirement

To obtain maximum economic benefit, the full irrigation requirement of a crop over all portions of the fields must be met. From a practical standpoint, this requires greater depths of irrigation to be supplied to the field than is indicated by the calculated irrigation water requirement. The depth of water necessary to fully supply the consumptive irrigation requirement is termed the field-irrigation requirement. The ratio of the consumptive irrigation requirement to the field irrigation requirement is called the field-irrigation efficiency. A field-irrigation efficiency of 70 percent was estimated for the sprinkler irrigation system. Table D-9 shows this field irrigation water requirement for the sandy soil.

Table D-10 shows the project irrigation requirements weighted by the cropping percentages assumed.

Reuse of Return Water

The irrigation and drainage system layouts proposed for the three sandy soil sites can be easily adapted to reuse water lost to surface and part of the subsurface runoff. At gates in the drainage ditch and at the low flow storage reservoir, water can be pumped back into the irrigation canal.

The amount of water which may be recovered for re-use can be estimated from similar operations in other parts of the country. This

Table D-9

IRRIGATION WATER REQUIREMENTS

Crop	Sandy Soil			Supplemental Water Requirement (inches)	Field ^{4/} Irrigation Water Requirement (inches)
	Consumptive ^{1/} Use	Effective ^{2/} Rainfall	Soil ^{3/} Moisture		
	(inches)	(inches)	(inches)		
<u>Corn</u>					
May (1/2)	1.10	0.95	0.15	-	-
June	4.17	2.21	0.35	1.61	2.30
July	7.86	2.16	-	5.70	8.14
August	6.88	2.15	0.21	4.52	6.46
September (1/2)	2.07	0.88	1.19	-	-
<u>Soybeans</u>					
June	4.26	2.22	0.50	1.54	2.20
July	8.27	2.21	-	6.06	8.66
August	6.21	2.09	0.86	3.26	4.66
September (1/3)	1.07	0.53	0.54	-	-
<u>Spring Grains</u>					
April	1.24	1.24	-	-	-
May	4.72	2.26	0.40	2.06	2.94
June	8.15	2.68	-	5.47	7.81
July (1/2)	2.46	0.96	1.10	0.40	0.57
<u>Alfalfa</u>					
April	2.46	1.90	0.56	-	-
May	4.95	2.30	0.19	2.46	3.51
June	7.41	2.57	-	4.84	6.91
July	8.48	2.25	-	6.23	8.90
August	7.16	2.18	-	4.98	7.11
September	4.57	1.77	2.25	0.55	0.79
<u>Grass</u>					
April	2.11	1.86	0.25	-	-
May	4.07	2.20	0.15	1.72	2.46
June	6.05	2.41	-	3.64	5.20
July	7.06	2.06	-	5.00	7.14
August	6.08	2.08	-	4.00	5.71
September	4.09	1.75	1.10	1.24	1.77

^{1/} From Table D-7^{2/} From Table D-8 using 8 out of 10 year rainfall from Table D-6.^{3/} Using 75 percent of the readily available root zone moisture, (Table D-3), as available to the crops with 25% being applied at the beginning of the season and 50 % at the end of the season.^{4/} Assuming a field irrigation efficiency of 70 percent.

Table D-10

WEIGHTED MONTHLY IRRIGATION REQUIREMENTS

Sandy Soil

<u>Crops</u>	<u>Corn</u>	<u>Soybeans</u>	<u>Spring Grains</u>	<u>Alfalfa</u>	<u>Grass</u>	<u>Total (inches)</u>	<u>Total (AcFt/Ac)</u>
<u>Cropping Intensity</u>	50.0	25.0	10.0	10.0	5.0		
<u>Months</u>							
April	-	-	-	-	-	-	-
May	-	-	0.29	0.35	0.13	0.77	0.06
June	1.15	0.55	0.78	0.69	0.26	3.43	0.29
July	4.07	2.16	0.06	0.89	0.35	7.53	0.63
August	3.23	1.16	-	0.71	0.28	5.38	0.45
September	-	-	-	0.08	0.09	0.17	0.01
<u>Total</u>						<u>17.28</u>	<u>1.44</u>

may be about one third of the application loss or 10 percent of the diversion requirement.

Diversion Requirements

Total water requirements at the diversion point are equal to the field irrigation requirements plus conveyance losses. The conveyance losses include seepage, gate leakage and regulation waste incurred in distributing water throughout the irrigation system. Allowance for these losses must be made to assure that the field irrigation requirements are met. A conveyance loss of 15 percent was estimated for the irrigation system.

Table D-11 shows the maximum monthly diversion requirements assuming the entire area of 19,400 net acres is sandy soil.

Peak Period Irrigation Requirements

The irrigation system must be capable of delivering water to satisfy crop demand of the peak short periods and should be designed for the peak period demand flow. Table D-12 shows the peak period computations and the resulting irrigation system design demand flow of one cubic foot per second per fifty irrigated acres.

Table D-11

TOTAL DIVERSION REQUIREMENTS

Sandy Soil

(For a net irrigated area of 19,400 acres)

<u>Month</u>	<u>Diversion</u> ^{1/} <u>Requirement</u> (Ac Ft)	<u>Supplied by</u> ^{2/} <u>Sludge</u> (Ac Ft)	<u>Supplied by</u> ^{3/} <u>Reuse System</u> (Ac Ft)	<u>Required from</u> <u>other Sources</u> (Ac Ft)
April	---	665	---	---
May	1,370	688	137	545
June	6,610	665	661	5,284
July	14,370	688	1,437	12,245
August	10,260	688	1,026	8,546
September	<u>230</u>	<u>665</u>	<u>---</u>	<u>---</u>
Total	32,840	4,059	3,261	26,620

^{1/} Values from Table D-10 adjusted for an estimated conveyance loss of 15%.^{2/} Using a continuous supply of 11.2 cfs.^{3/} Using 10% of the diversion requirement as return flow.

Table D-12

PEAK PERIOD IRRIGATION REQUIREMENT^{1/}

Sandy Soil

(For peak month of July)

(1) Crop	(2) Crop Area (Percent)	(3) Net Irrigation Application (1) 2/ Inches	(4) Monthly Consumptive Use (Um) Inches	(5) Peak Period Consumptive Use (Up) 3/ Inches/Day	(6) Peak Period Irrigation Interval (3) ÷ (5) Days	(7) Weighted Peak Period Consump- tive Use (2) x (5) Inches/Day	(8) Peak Period Diversion Requirement (7) x 1.681 4/ Inches/Day cfs/acre	(9)
Corn	50.0	1.25	7.86	0.32	3.9	0.16	0.27	0.0112
Soybeans	25.0	1.25	8.27	0.33	3.8	0.08	0.13	0.0054
Spring Grains	10.0	1.00	4.96	0.20	5.0	0.02	0.03	0.0012
Alfalfa	10.0	2.00	8.48	0.33	6.1	0.03	0.05	0.0021
Grass	5.0	1.00	7.06	0.28	3.6	0.01	0.02	0.0008
Total						0.30	0.50	0.0207

Irrigation System Design Demand Flow = One Cubic foot per second per Fifty irrigated acres.

1/ Method used for determining peak period consumptive use as shown in USDA, Soil Conservation Service Technical Release No. 21.

2/ Equals estimated 1/2 root zone storage.

3/ Derived from columns 3 and 4 using the relationship $Up = 0.034 Um$ 1.09 I - 0.09

4/ Using a 70% field irrigation efficiency and a conveyance loss of 15%.

Agriculture Development Criteria

Introduction

The criteria for development of the agricultural areas are based on the assumption that the Sanitary District will buy the land, install the irrigation, sludge distribution and drainage systems, and then rent or lease the land to qualified farmers.

Preliminary layouts and designs have been made of irrigation, drainage, and sludge distribution systems for the Phase 2 and 3 sites. Exhibit D-1 shows the location of the Phase 3 sites. The Phase 2 site has a gross area of 1,720 acres with 4 percent of the area estimated to be in roads and farmsteads leaving a net area of 1,6650 acres. A gross area of 21,500 acres has been used for each Phase 3 site with 10 percent of the area estimated to be roads, ditches, farmsteads, etc. leaving net cultivated area of 19,400 acres.

Leveling and Grading

A first step in the installation of the sludge disposal system will be leveling the land and grading of embankments on which to operate the sprinkler equipment. On the sandy soil sites, nearly level areas will be graded to give proper slope from the irrigation lateral to the tile drains and to construct roadway embankments three to six inches above the field level. The rolling terrain areas will require movement of larger quantities of earth to obtain required land slopes. Little change in the soil profile is expected with grading the upper five or six feet in the rolling sand areas. For this reason, stockpiling of the topsoil will not be required. In isolated places where topsoil is removed the sludge can be used to replace topsoil. The land will be graded in field sizes of 640 acres in the level areas and 20 or 40 acres for the rolling areas. The rolling dunes of Plainfield sand,

which are presently forested, will be left as conservation areas. Exhibit D-2 shows the area used to estimate the heavy leveling cost and Exhibit D-3 shows a typical 160-acre field layout.

Embankment roadways will be provided every 330 feet for the irrigation equipment. These roadways will be twelve feet wide and crop rows will run parallel with the roadways.

In the heavy soil areas leveling will be almost impossible because of the soil texture and shallow profile. Some grading will be done to make roadway embankments for operation of the sprinkler. On these areas, runoff protection will be provided by small storage reservoirs located throughout the area. This runoff will be pumped back on the land to prevent formation of sludge lagoons.

Drainage

A drainage system will be required to remove excess surface water from heavy rainfall and to keep the water table at a level tolerable to the crops. On the sandy soil sites the drainage system will consist of large open ditches at one mile intervals and tile drains at about 1,300 foot intervals, outleting into the open ditches. Additional open ditches will be constructed along the irrigation equipment roadway embankments if required. These small ditches will outlet at the controlled surface water inlet to the tile drains.

Existing open ditches will be used whenever possible, and the cost estimates have been adjusted to reflect the present drainage developments in the various areas.

The drainage system on the heavy soil areas will be basically the same as on the sandy soil sites except tile drains will be required at about 400 foot intervals.

Preliminary design of the drainage ditches is based on a runoff of 1.5 inches in 24 hours giving a design flow of 40 cubic feet per second per section of land. The size of exterior ditches around the area will be increased to carry excess runoff from adjacent areas. Criteria used in the preliminary design of the drainage channels were:

- (a) minimum depth = 3 feet
- (b) minimum bottom width = 3 feet
- (c) maximum velocity = 2.5 feet per second
- (d) side slopes 1:1 (ditch excavated oversize and banks allowed to slump to a stable cross section)
- (e) coefficient of rugosity "n" (Manning) = 0.035

The tile drain lines will be twelve and fourteen inch clay tile based on a drainage coefficient of about 0.5 inches per 24 hours. Each tile line would cover 80 acres and surface inlets provided at 330 foot intervals along the tile line. These inlets would be gated in order to close them during sludge application. The tile outlet to the drain ditch would also be gated to allow controlled releases from the tile line.

Exhibit D-3 shows the tile drain layout and exhibits D-4, D-5, D-6, and D-7 show the main drainage system layouts for the alternative sites.

Sludge Distribution

The sludge distribution system design has been based on a 24 hour, year-around operation.

On heavy soil in rolling terrain, sludge application will be by sprinkler at all times of the year.

Sludge application on the sandy soil sites will be by sprinklers at all times except when it is applied to growing crops. Surface irrigation methods will be used to distribute the sludge during this period. Since the sandy areas will be leveled, there should be no problem in using this method of application. When the ground is frozen, the surface water intlets to the tile drains will be closed and the sludge ponded on the fields. With the land leveled and the embankment roadways, little sludge would be carried by surface runoff from the land.

The sludge distribution layout for each area will consist of a 30-inch buried asbestos-cement pipeline across the center of the area and lateral pipelines at one mile intervals. Sub-laterals of 6-inch buried asbestos-cement pipeline will be spaced at quarter-mile intervals across the cropped area. The irrigation and sludge distribution lateral and sub-lateral systems were combined for the sandy soil areas. Exhibit D-3 shows the sublateral sludge distribution system layout and Exhibits D-4, D-5 D-6, and D-7 show the main and lateral sludge distribution system layouts.

The system has been designed so that the sludge may be distributed by either surface or sprinkler methods. When surface distribution of the sludge is required, the sludge would run from the main pipe into the laterals and at the sublateral turnout gated pipe would be used to spread the sludge. When sprinkler distribution is used, the sludge would be pumped into the laterals by booster pumps and applied by sprinklers.

Irrigation

The sludge distribution system will be used for the irrigation water and the size of pipes carrying sludge and irrigation water are based on irrigation flows. Open canals will be used whenever possible to deliver irrigation water to the lateral pipe system.

Criteria used for the preliminary design of the lateral pipelines were:

- (a) Class 150 and 200 asbestos-cement pipe
- (b) Pipe buried three feet below the ground surface
- (c) Maximum velocity 7.0 fs at peak flow
- (d) Minimum velocity 2.0 feet per second with sludge alone

Table D-12 gives the peak period demand flow used to size the irrigation facilities. In the three sandy soil sites, about 15 percent of the soil is heavy textured. Essentially no irrigation was assumed for this soil so that a peak period diversion requirement of 320 cfs resulted for the net area of 19,400 acres. The preliminary design of the irrigation facilities to bring the water to the area is based on this demand flow.

Irrigation Water Source

Ground water investigations showed that only the St. Anne area may have ground water sufficient for an irrigation supply. A surface water supply will be required for the Coal City and Essex areas and two rivers (the Illinois and the Kankakee) with sufficient excess flow to meet the irrigation requirement are near these sites. The Kankakee river is closest to all three sandy soil sites, and the cost of conveying the water to the areas would be low. But because the peak period diversion requirement is nearly equal to the summer minimum flow in the Kankakee it was

not used as the irrigation water source.

The Illinois river has been used as the irrigation water source for the Coal City and Essex sites and ground water has been used for the St. Anne site.

For the Coal City and Essex areas a pumping plant will be located on the Illinois River Dresden pool. Pump lifts of 60 to 70 feet will be required to deliver the Illinois River water to the two areas. The conveyance system utilizes reinforced concrete pipe and open canal from the river to the sites.

The following criteria were used for the preliminary design of the main canal from the river to each site:

- (a) side slopes 1.5 horizontal to 1 vertical
- (b) bottom width to depth ratio about 2:1
- (c) coefficient of rugosity "n" (Manning) = 0.016
- (d) velocity = 5 feet per second
- (e) three inch unreinforced concrete lining,

Irrigation Method

Sprinklers will be used for distribution of the irrigation water. Sprinkler application is necessary in the sandy soil areas because the water intake rate of the soil is too high for good furrow application.

Irrigation by sprinkler will also reduce the quantity of water required because of the higher efficiencies which can be obtained. It is also a much easier method for farmers to learn to use.

To keep labor requirements low, a high pressure automatic system was assumed in the preliminary design. Estimates for the irrigation

system are based on using a "big gun" sprinkler which would be towed across the field. This system will require a pressure of 80 to 100 psi at the gun nozzle. A gun sprinkler similar to the "Water Winch" manufactured by Ag Rain, Inc. of Havana, Illinois or the "Rain Wagon" manufactured by Nelso Mfg. Co. of Peoria, Illinois was assumed. A winch, for continuous move operation, with cable and small gasoline engine and a flexible hose 660 feet long are required with either sprinkler gun. One sprinkler will be required for each 80 acres of irrigated area. The six-inch sublateral pipeline with turnouts at 330 foot intervals are designed to carry a peak flow of 1.3 cfs. Each sublateral covers an area of 80 acres and one "big gun" sprinkler will operate on each sublateral. At this peak rate 1.6 inches of water can be applied to the 80 acres in four days.

Subirrigation, as presently practiced in the St. Anne area may be practical on some parts of the sandy soil areas. The addition of sludge will require a greater control of ground water using the project drainage system, and this may make subirrigation incompatible with the sludge distribution system. For this reason a subirrigation system has not been assumed. If this system can be used with the sludge distribution system, costs for irrigation could be reduced.

Conservation Areas

Trees will be required throughout the site area for both esthetic and windbreak purposes. The sprinkler method of distribution will require windbreak to give a good distribution pattern on windy days. Two or three rows of trees should be planted at required intervals. In addition, a strip of trees and bushes about 100 feet wide should be planted around the site for esthetic purposes. Trees should be kept along creeks and rivers and on sand ridge tops.

All of the areas will provide cover for wildlife. In addition, the irrigation equipment roadway embankments will provide grass cover for wildlife.

Tinley Park Area.

The preliminary design criteria used for the Phase 2 site is similar to that used for the heavy soil area of the Phase 3 alternative sites. Because of the fine textured soil existing at the Tinley Park site no irrigation will be required. Exhibit D-8 shows a typical layout for 160 acres of the Tinley Park site.

Conveyance of sludge to the Tinley Park site will initially be by truck. The sludge distribution system designed for this area consists of truck unloading pits with pumps to pump from the pits into the buried pipeline systems. A pit and booster pump will be required for each area of about 160 acres. The pipeline layout is similar to that described for the Phase 3 alternative sites. In 1972, when the pipeline is constructed to the Phase 3 area, connections will be made to each booster pump.

In addition to the sludge distribution system, grassed waterway drainage channels and some tile drainage will be required. Near the center of the area a holding reservoir will be provided to control runoff. Protective dikes along the existing drainage ditch will also be provided. Gated inlets to the drainage ditch will be part of the protective system. Embankments will be required at some points along the site boundary. These will be used to prevent runoff from the area. The distribution of sludge on this area will be similar to the Andres area of the Phase 3 sites. Distribution will be by sprinkler at all times of the year with the moving sprinkler equipment being used.

Methods of Operation

Organization

Organization for the distribution of sludge and for the agricultural operation assume that the Sanitary District will buy the gross-area of 21,500 acres. The land would be rented or leased back to the farmers in 320 to 640 acre tracts.

A tentative organization for operation of the project is shown on Exhibit D-9. This assumes that the District will contract with a farm management firm to handle the agricultural operation and land rental agreements. The agricultural personnel would be headed by a farm management supervisor who would coordinate sludge distribution to the farmland. The sludge distribution personnel would be employed by the District and under the direct supervision of a Sludge Distribution Supervisor.

Responsibilities of each entity are highlighted as follows.

(a) Sludge Conveyance

This segment of the organization would have direct responsibility under the District for the physical operation and maintenance of the pumping stations, conveyance lines and distribution pipelines down to the farm turn-outs. They would provide data on the volume of sludge for disposal and be responsible for delivery at the time and place specified by the farm management supervisor.

(b) Farm Management

This segment of the organization, composed of agricultural specialists provided by the professional farm management firm would be responsible for sludge application operations at the farm level. They would provide the location for disposal of sludge in areas compatible with the sludge application schedule, loading rates, cropping patterns, etc. They would be responsible also for leasing the land to farm operators, collection of rentals, controlling surface run-off and unnecessary deep percolation, irrigation distribution and application rates, cropping patterns, advice to farmers, etc.

Sludge Loading Rate

In using the sludge as a beneficial soil amendment and as fertilizer it will not be economical or practical to use a uniform annual sludge application over the entire project area. The application rate will be related to such factors as soil type, crops grown, field layout and farming method (irrigation or non-irrigated).

Loading Rate for Fertilizer Benefit

The principal criteria used to arrive at a loading rate for the fertilizer benefit is the amount of nitrogen in the sludge.

A study of controlled trials on crop yields to determine the value of digested sludge indicated that an annual application rate of about ten tons dry weight, of digested sludge containing about 2.5 percent total nitrogen (50 lb of total nitrogen per ton) is safe and will provide sufficient

available nitrogen to produce high yields 1/ 2/ 3/. The trails were carried out on both sandy and medium-textured soils.

Tests to determine the release of available nitrogen from digested sludge, using an incubation procedure of sludge mixed with soil, were performed by Anderson and Stepehnson 4/ 5/. They found that about 20% of the nitrogen from digested sludges, was released in the first growing season after application. Using a ten ton per acre annual loading rate and the Sanitary District's sludge containing 5% nitrogen, the 20% release rate would provide about 200 pounds of nitrogen to the crop. A 140 bushel corn crop requires about 200 lbs of nitrogen for the grain and stalk growth. Due to leaching and other losses only about 60 percent of the nitrogen applied is available to the crop. The additional nitrogen required will be available from continued further release of the nitrogen by the sludge.

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- 1/ "Digested Sewage Sludge for Soil Improvement" L. Herbert A. Lunt Bulletin (22) April 1959. Conn. Agri. Exp. Sta.
 - 2/ "Utilization of Liquid Sludge," by Robert C. Merz, Water and Sewage Works, November 1959.
 - 3/ "The Case for Sludge as a Soil Improver," by Herbert A. Lunt, Water & Sewage Works, August 1953.
 - 4/ "Comparative Analysis of Sewage Sludges," by M. S. Anderson, Sewage and Industrial Wastes, February 1961.
 - 5/ "Availability of Nitrogen in Sewage Sludges," by R. J. Stephenson, Sewage and Industrial Wastes, January 1955.

A ten ton per acre per year loading rate was, therefore, used for corn grown on the project area. An initial heavier application on low fertility soils may be required to bring the soil nitrogen level up to a point acceptable to high corn production.

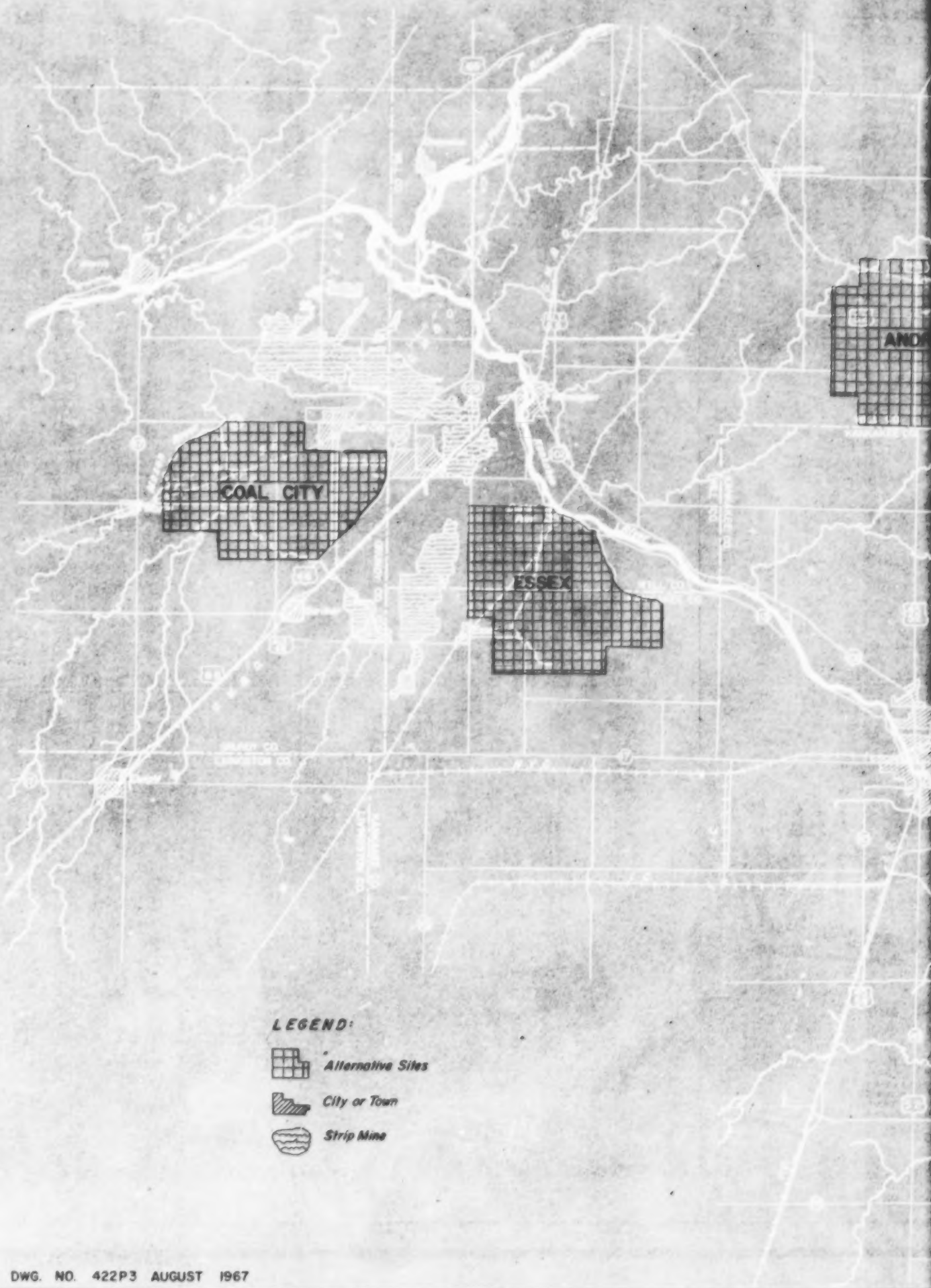
Loading Rate for Land Reclamation

In the sludge application schedules shown on Table D-2 and D-3 certain periods of the year and parts of each month are used to apply sludge to the grass areas. During these periods application of the sludge to the cropped areas is not possible because of the farming operations and climatic conditions. At these times the best use of the sludge will be to reclaim poor soil areas. In the "reclamation" operation the sludge would be applied at rates of 200 tons per acre in period of from one to five years. Both the cities of New York, New York and San Diego, California are using this type of operation on a large scale to develop non-productive land area into landscaped parks with the sludge applied in a period of several months. This method of utilization would be particularly adaptable on any of the three sandy soil sites to reclaim the very marginal plain field sand soils contained there.

Several methods of incorporating of the heavy sludge applications into the soil could be used. The City of San Diego incorporates the sludge into the soil by mixing it with the top 18 inches of soil before the sludge dries. New York City incorporates the sludge into the top layer of soil after it dries. Another method of applying the sludge would be an adaptation of a method developed by Clarence H. Hansen at Michigan State University. Mr. Hansen placed a thin continuous layer of asphalt at a depth of 24 inches. This barrier then serves as an "artificial hardpan" and increases the moisture holding capacity of the root zone.

A layer of sludge placed at a depth of about 24" may be used to increase the root zone moisture holding capacity of the sandy soils above any increase expected by mixing the sludge with the soil. The placement of the sludge in a continuous layer could be accomplished with a type of plow presently used to invert soils which have been covered with sand from river overflow.

On the sandy soils the heavy sludge application could be accomplished by ponding sludge on bare land and intermittantly plowing the sludge cake under to mix it with the underlaying sand. Using this method a field could possibly be in crop production within a year after reclamation was begun. An alternative method for the land reclamation procedure may be to apply the same amount of sludge on a larger area of reeds canary grass over a period of three to five years. This method may be aesthetically more desirable and there would be less nitrate leached into the groundwater particularly if the grass was removed for hay.



LEGEND:



Alternative Sites

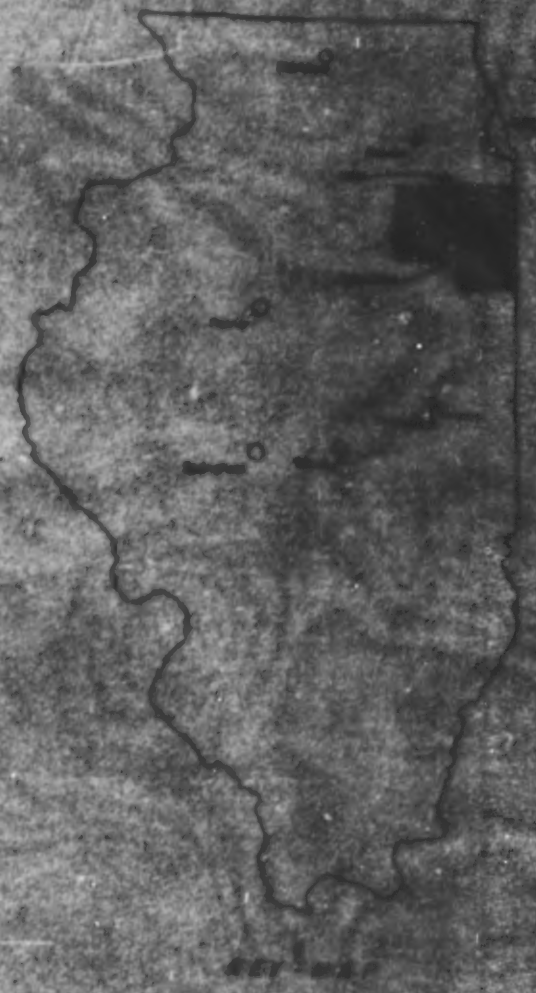
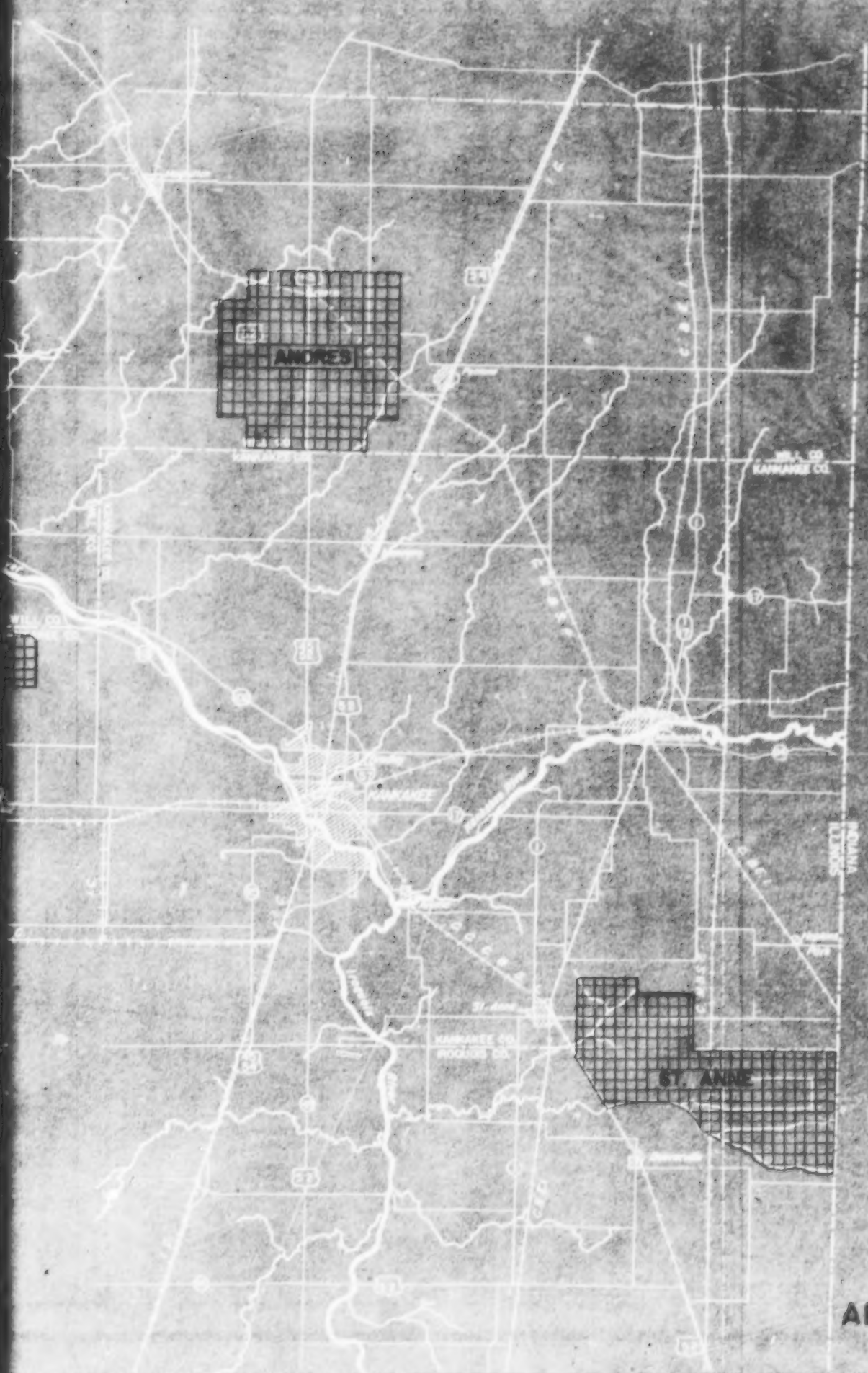


City or Town



Strip Mine

A



LEGEND:

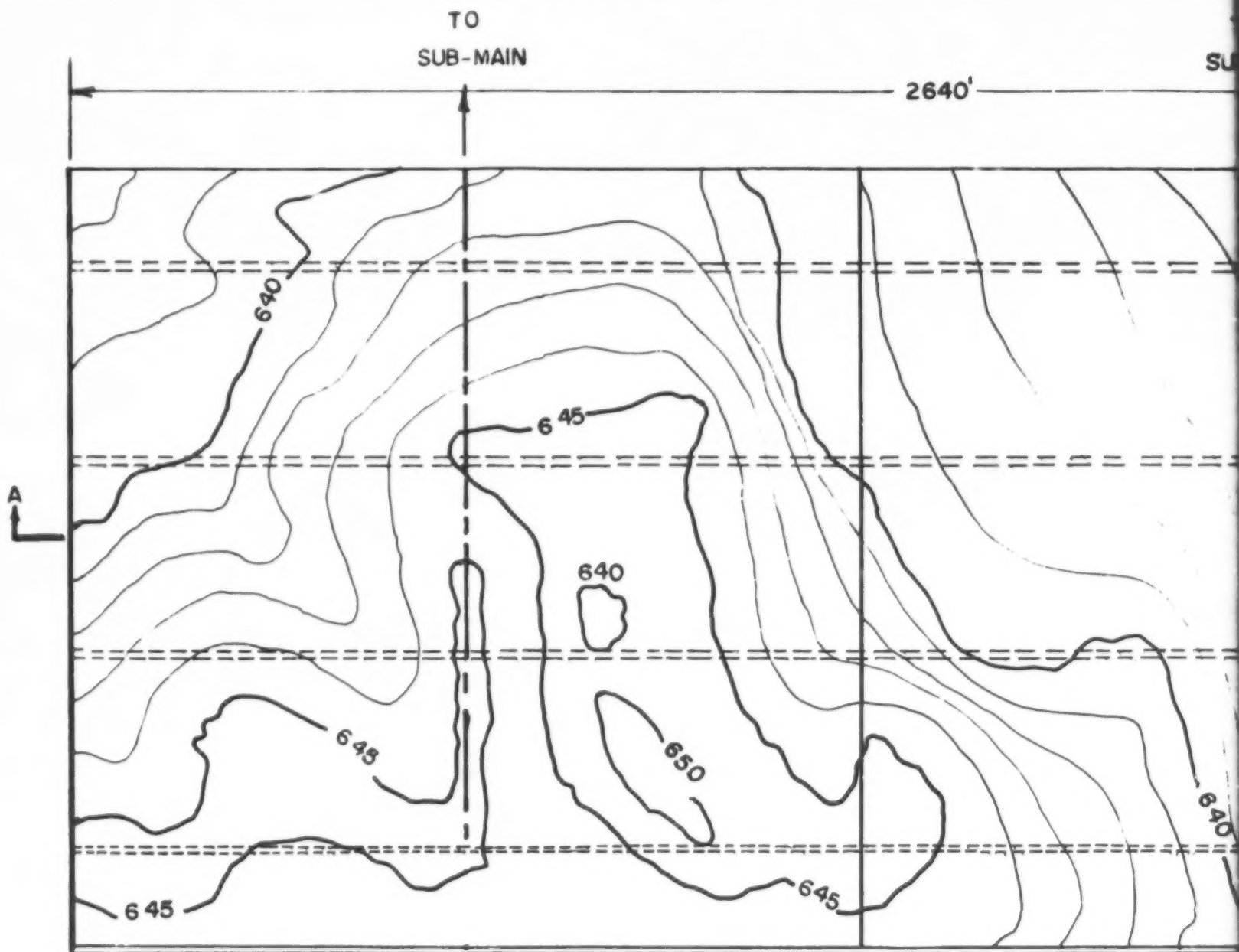
- Gravel pit area
- Densely populated area
- Recreational area
- Miss spot area

Scale 0 1 2 3 4 Miles

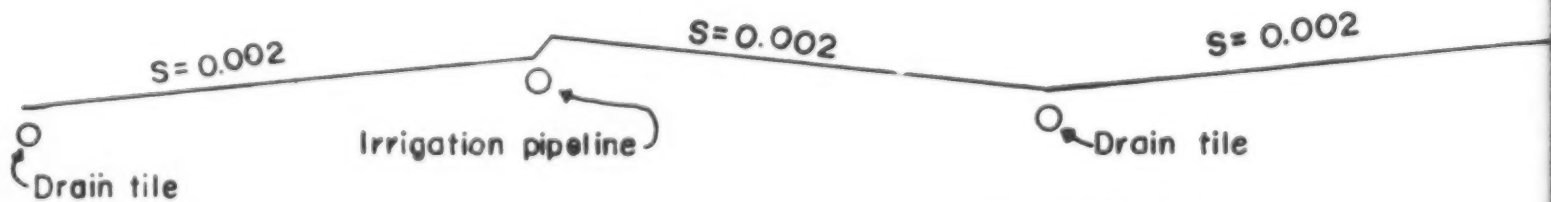
LAND RECLAMATION PROJECT

ALTERNATIVE PHASE 3 SITES

B



TYPICAL 80 ACRE AREA
WHERE HEAVY LEVELING IS REQUIRED



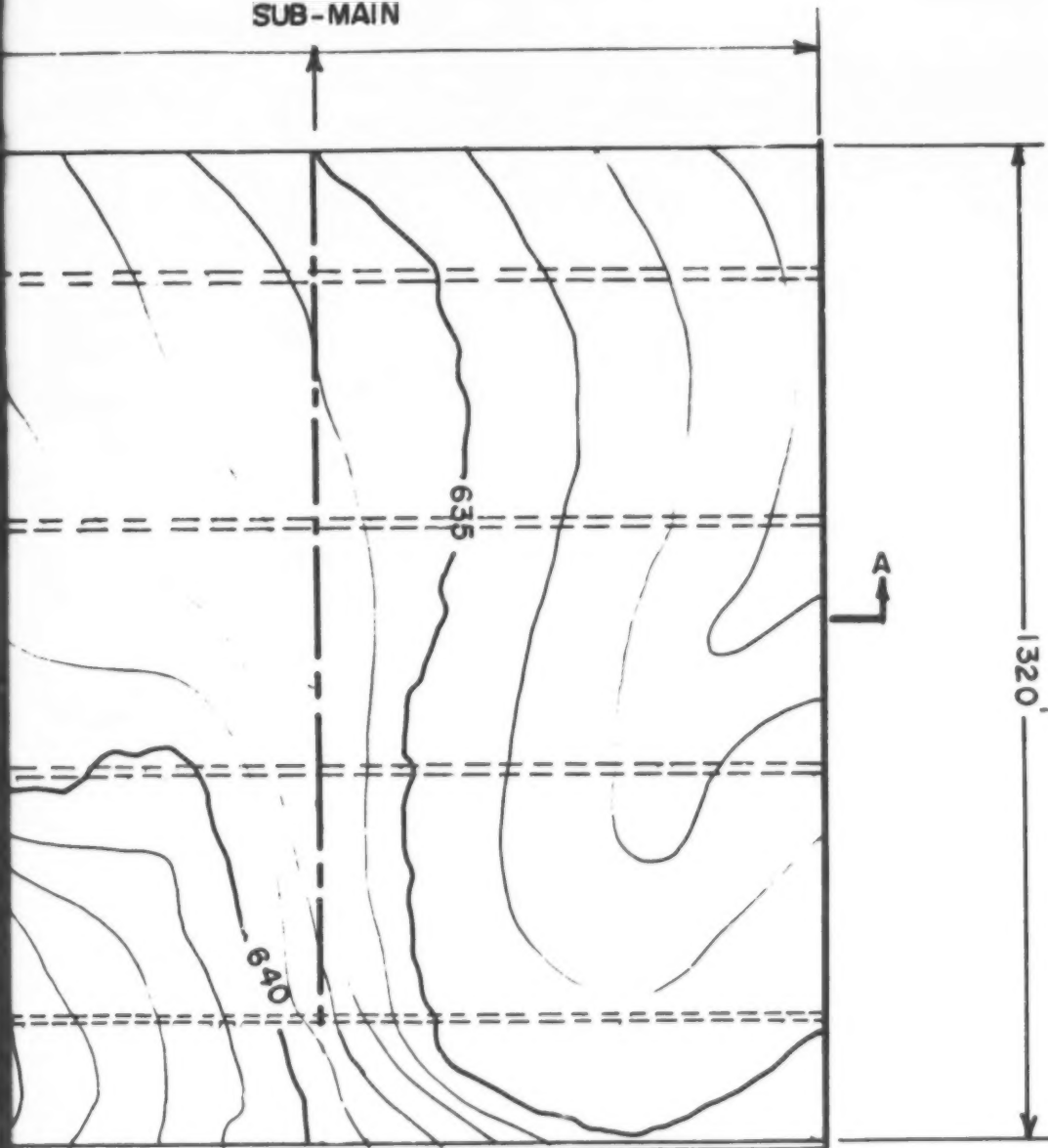
SECTION A-A
(AFTER LEVELING)

EXHIBIT D-2

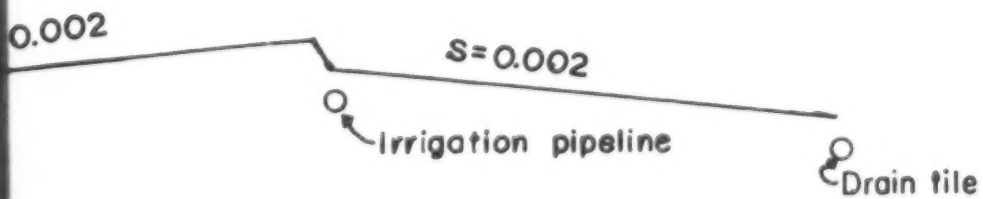
TO
SUB-MAIN

LEGEND

- LATERAL
- TILE DRAIN
- ===== EMBANKMENT ROADWAY
- ===== OPEN DITCH



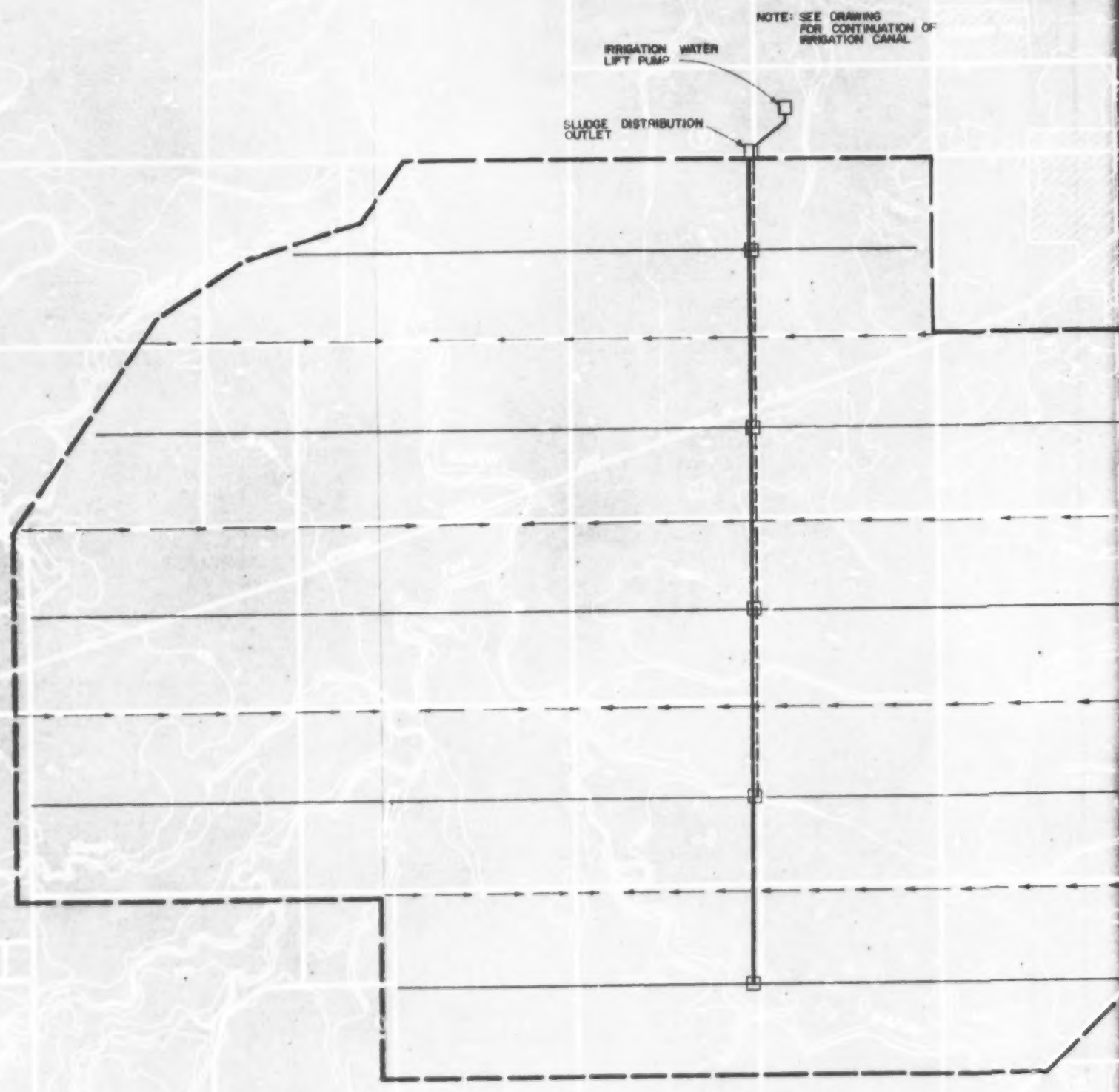
AREA
G IS REQUIRED



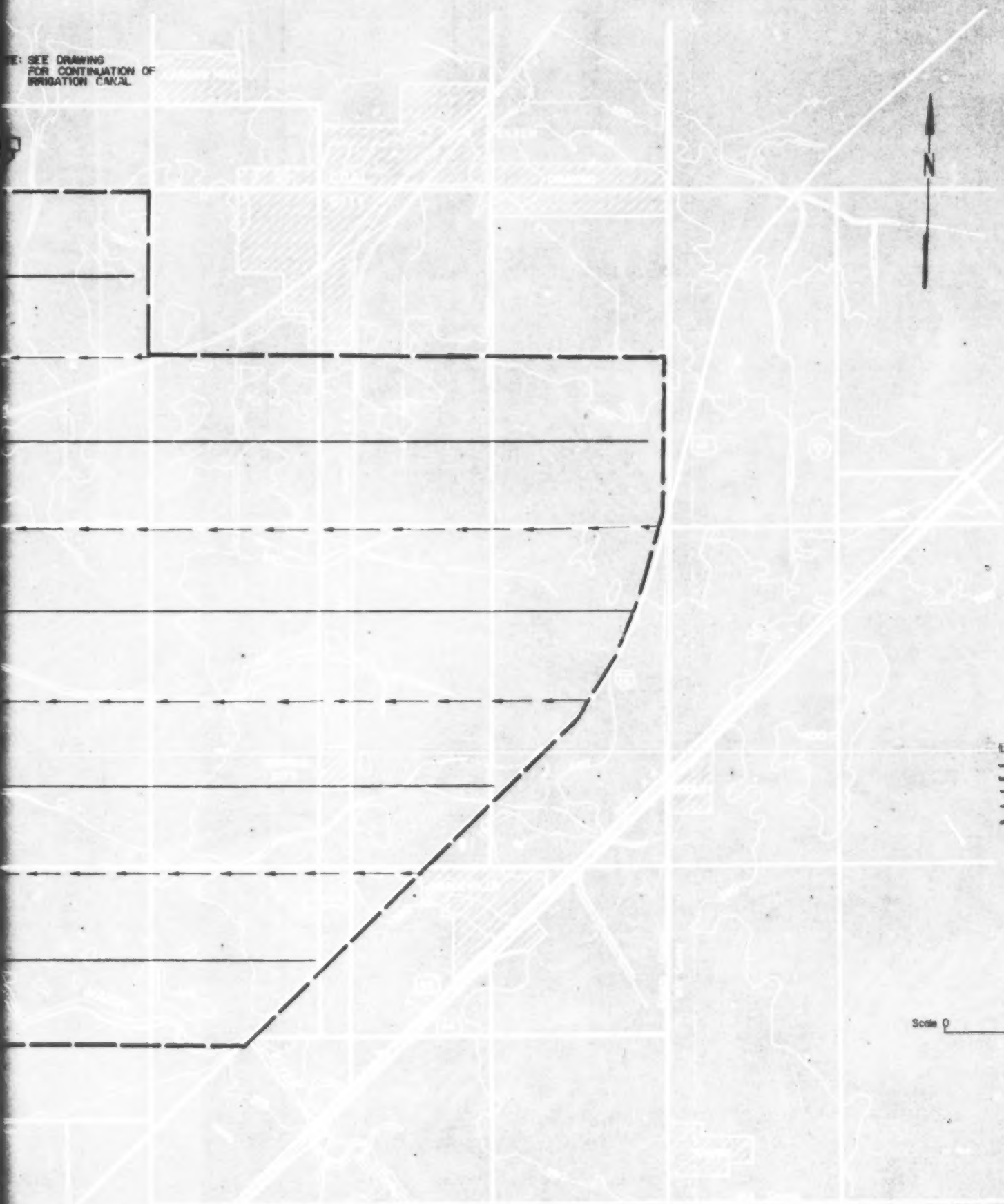
LAND RECLAMATION PROJECT

LEVELING DEVELOPMENT PLAN

B



SEE DRAWING
FOR CONTINUATION OF
IRRIGATION CANAL

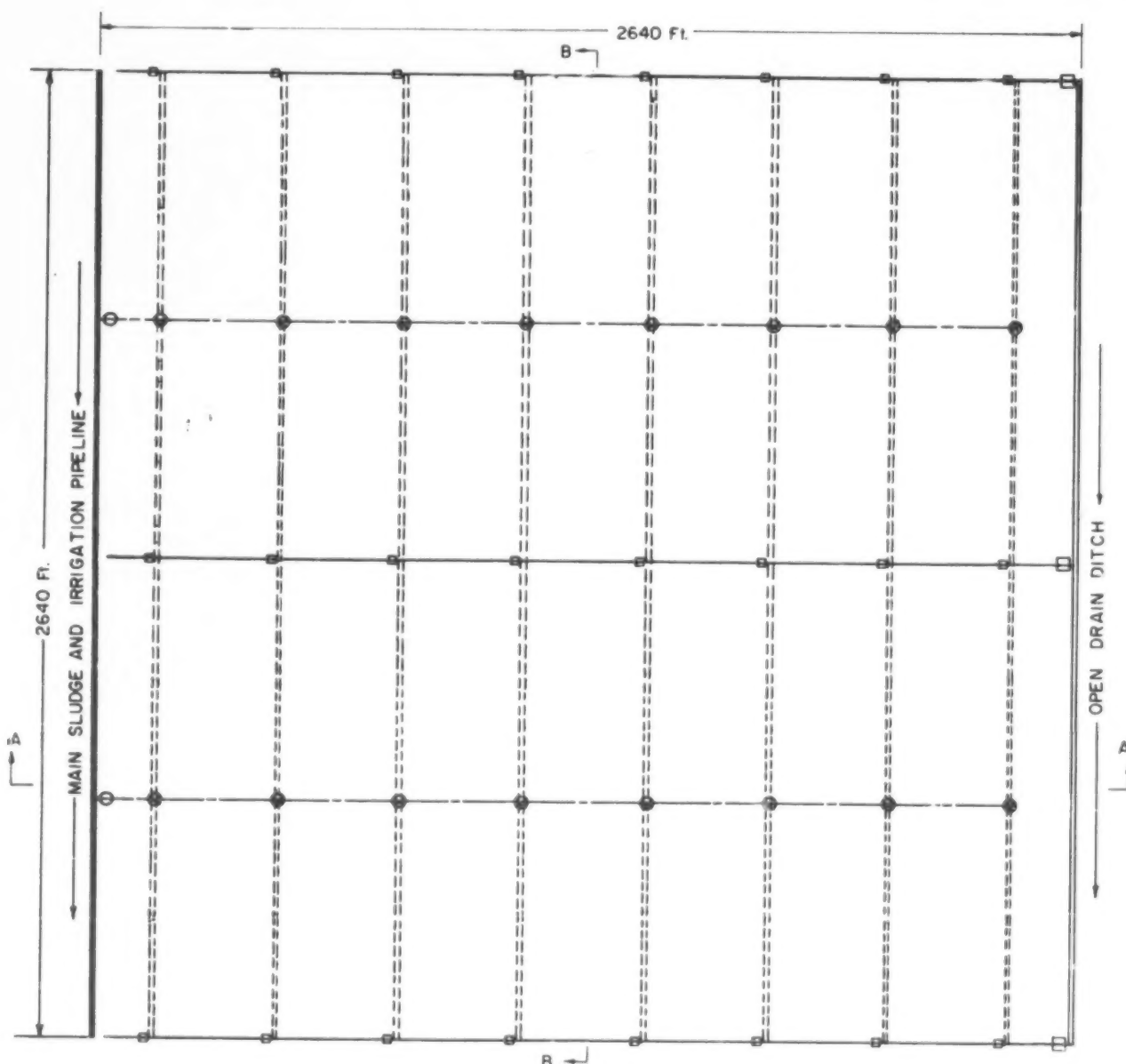


- LEGEND:
- OPEN CANAL
 - PROJECT BOUNDARY
 - LATERALS
 - DRAINAGE DITCHES
 - SLUDGE DISTRIBUTION PIPELINE
 - BOOSTER PUMPS

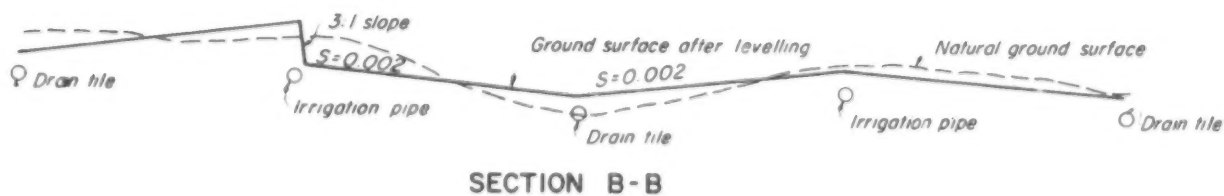
Scale 0 1/2 1 Mile

LAND RECLAMATION PROJECT
COAL CITY SITE DEVELOPMENT PLAN

B

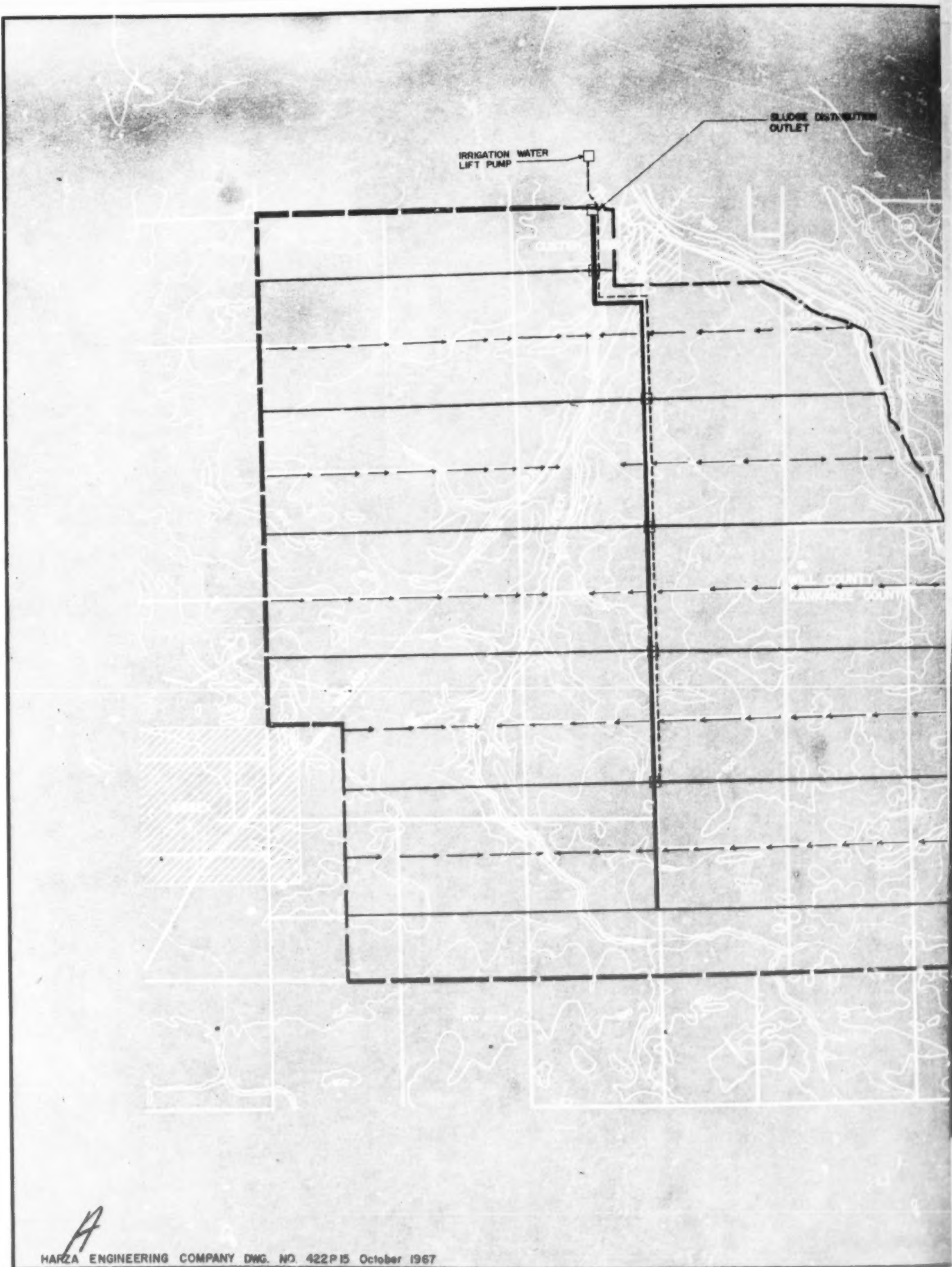


TYPICAL 160 ACRE LAYOUT



- ===== EMBANKMENT ROADWAY
- TILE DRAIN
- IRRIGATION AND SLUDGE LATERAL PIPELINE
- ===== OPEN DRAIN DITCH
- MAIN SLUDGE AND IRRIGATION PIPELINE
- TURNOUT VALVE FROM MAIN PIPELINE
- TURNOUT VALVE FROM IRRIGATION LATERAL
- CONTROLLED DRAIN TILE OUTLET AND SURFACE WATER INLET
- CONTROLLED SURFACE WATER INLET TO TILE DRAIN

LAND RECLAMATION PROJECT
ON FARM
DEVELOPMENT PLAN



WATER DISTRIBUTION
PLAN



LEGEND

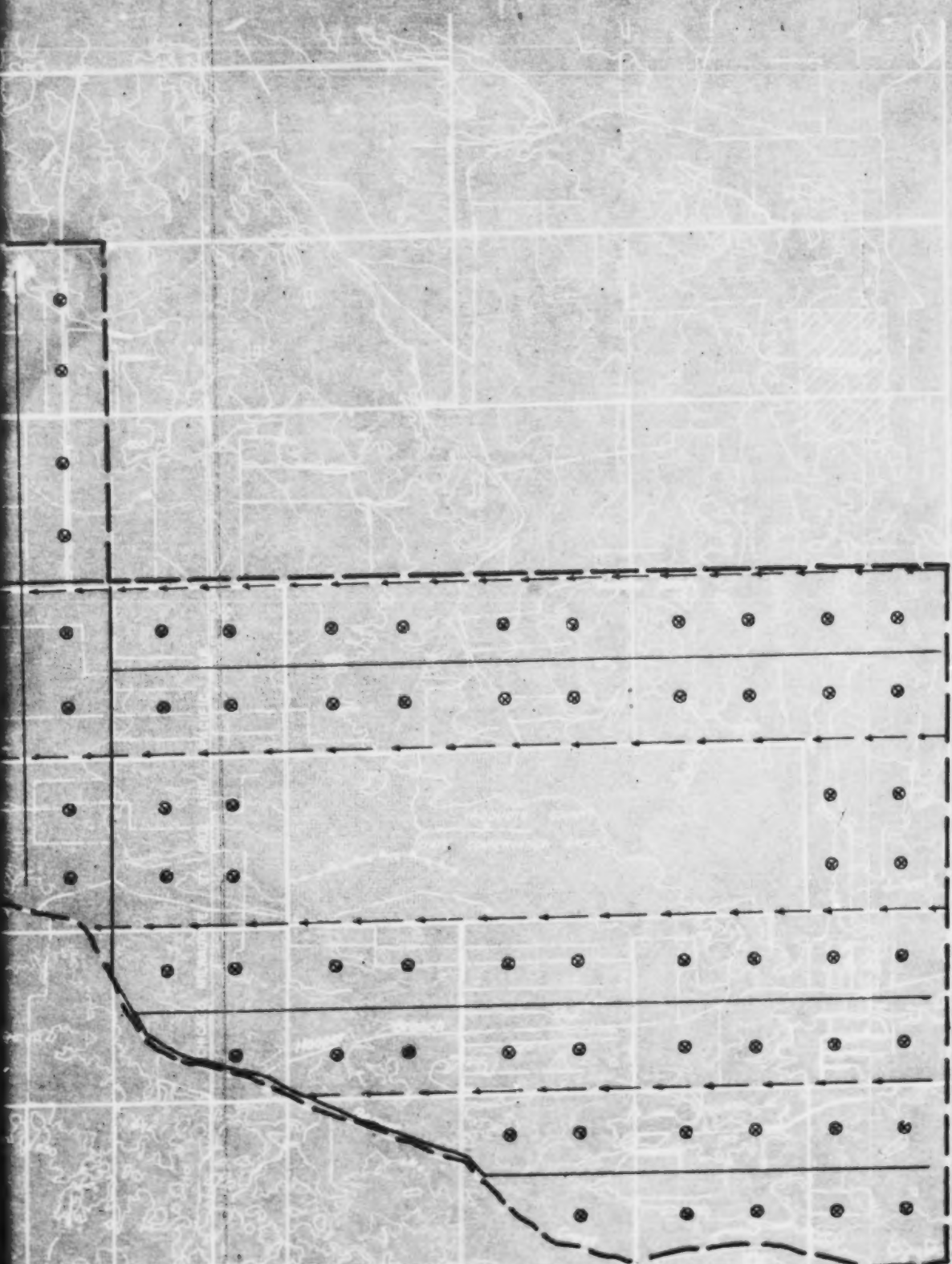
- PROJECT BOUNDARY
- LATERALS
- SLUDGE PIPELINE
- DRAINAGE DITCHES
- OPEN CANAL
- BOOSTER PUMP

Scale 0 2000 4000 Feet

LAND RECLAMATION PROJECT
ESSEX SITE
DEVELOPMENT PLAN

B

SLUDGE DISTRIBUTION
OUTLET

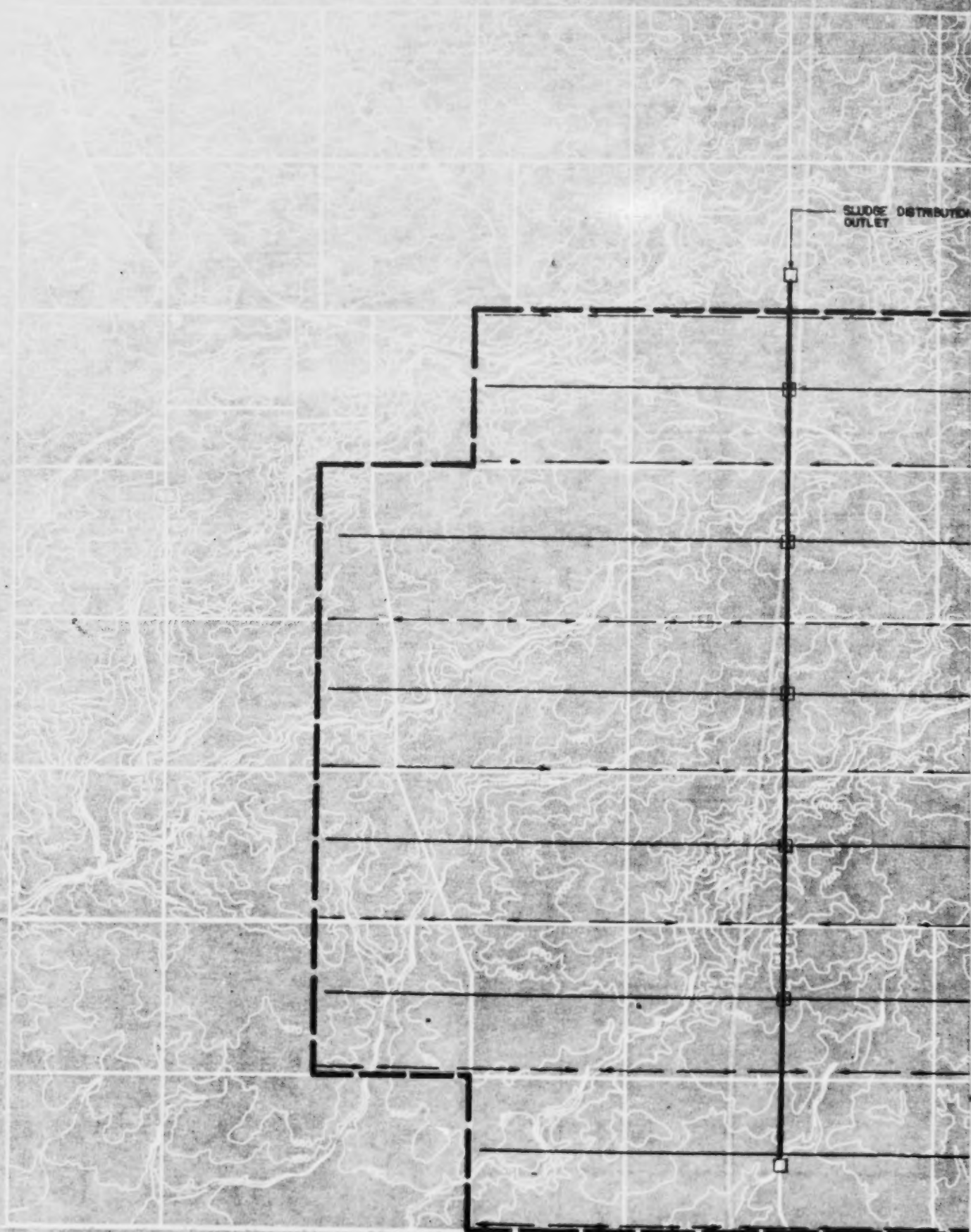


LEGEND:

- PROJECT BOUNDARY
- LATERALS
- - - DRAINAGE DITCHES
- - - SLUDGE DISTRIBUTION PIPELINE
- BOOSTER PUMP
- ⊗ IRRIGATION WELLS

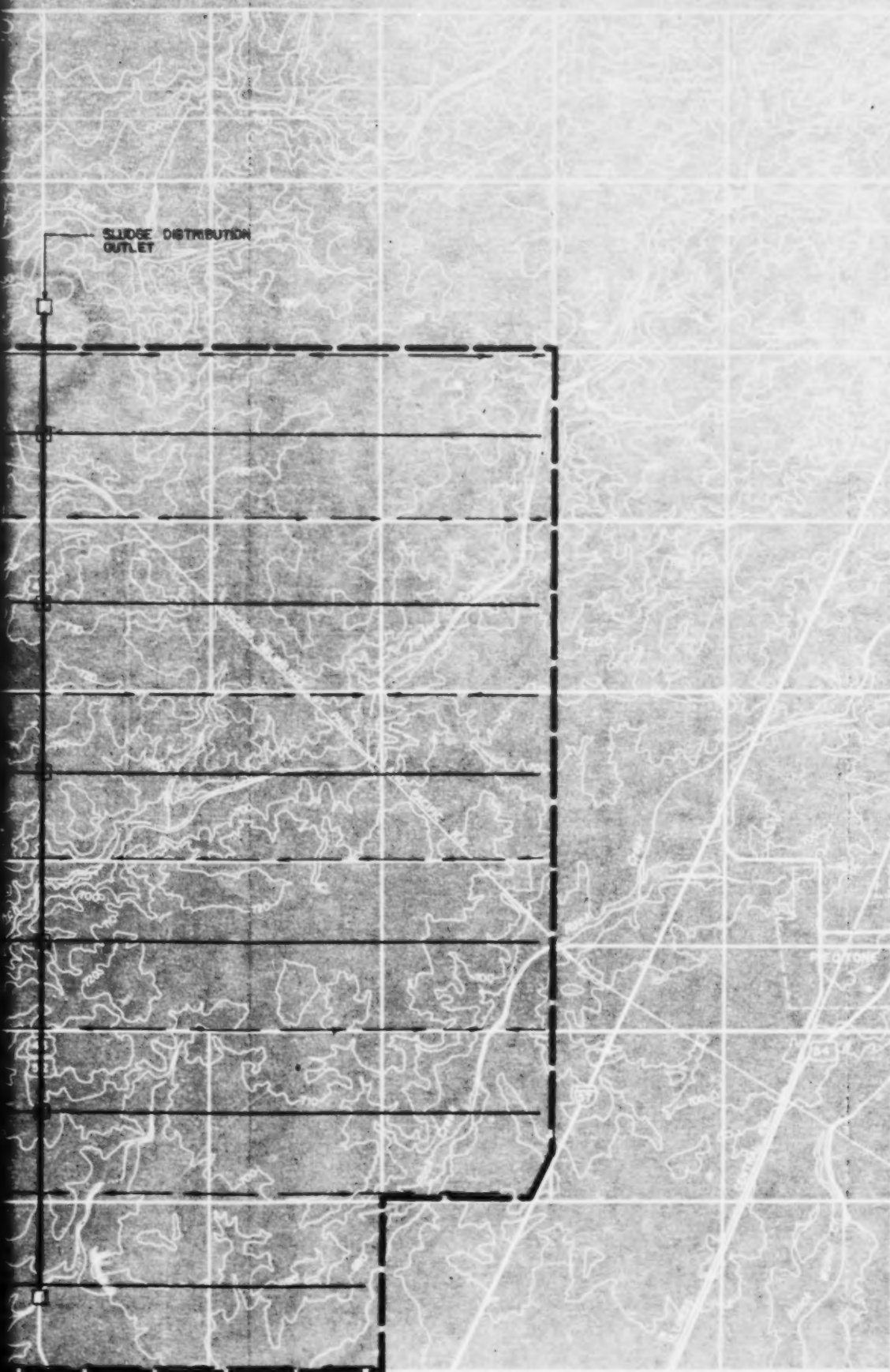
Scale 0 1000 2000 3000 4000 5000 Feet

LAND RECLAMATION PROJECT *B*
ST. ANNE SITE DEVELOPMENT PLAN



SLUDGE DISTRIBUTION
OUTLET

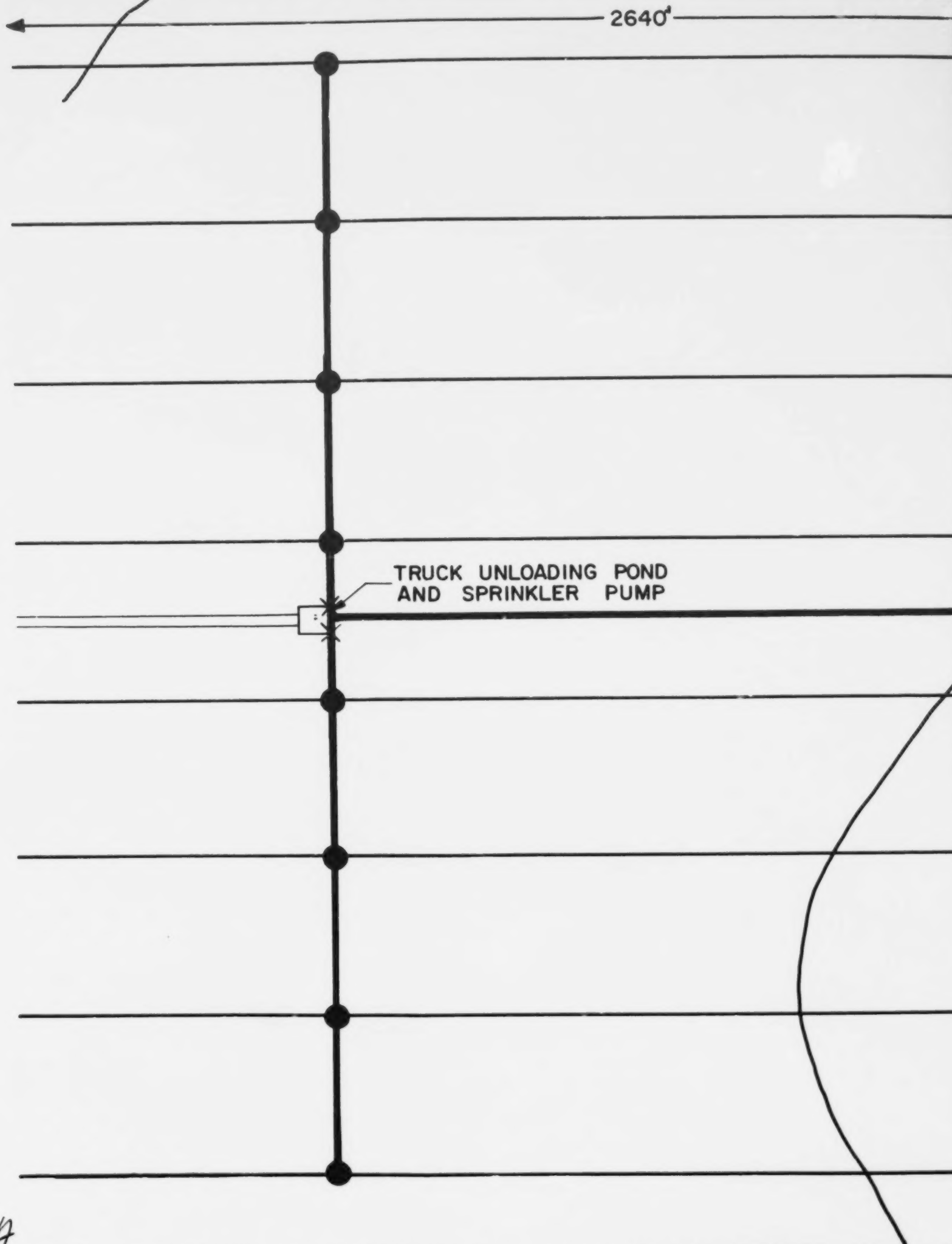
A



- LEGEND**
- PROJECT BOUNDARY
 - LATERALS
 - DRAINAGE DITCHES
 - SLUDGE DISTRIBUTION PIPELINE
 - BOOSTER PUMP

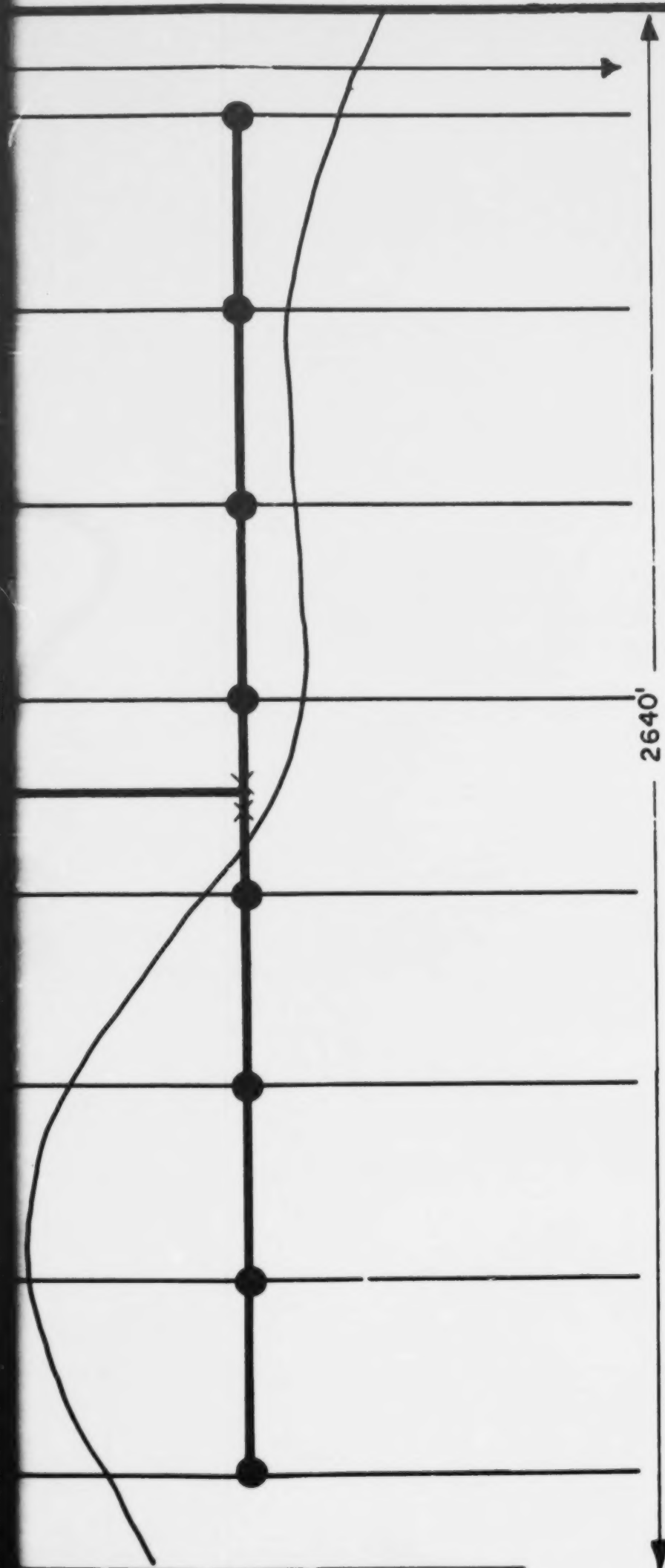
Scale 0 1000 2000 3000 4000 5000 Feet

LAND RECLAMATION PROJECT **B**
ANDRES SITE DEVELOPMENT PLAN



A

HARZA ENGINEERING COMPANY DWG. NO. 422 P 16 OCTOBER 1967

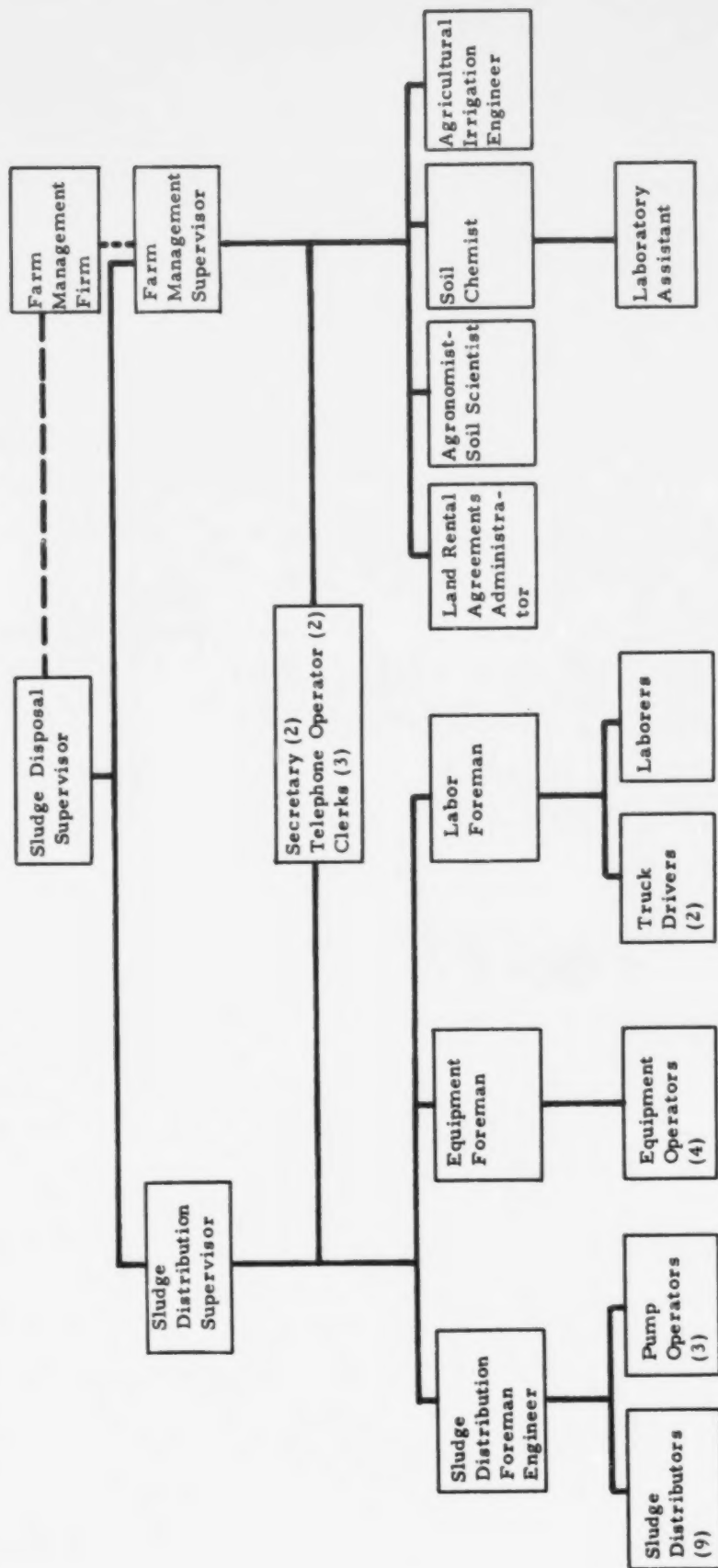


LEGEND

-  6" ASBESTOS CEMENT CLASS 150 PIPE
-  6" VALVES & FITTINGS
-  OUTLET VALVES
-  GRASSED DRAINAGE CHANNELS
-  FILL EMBANKMENT (from drainage channel excavation)
-  SPRINKLER EQUIPMENT GRADED ROADWAYS (12' wide)
-  20' WIDE TRUCK ROAD
-  UNLOADING POND

LAND RECLAMATION PROJECT

TINLEY PARK SITE
TYPICAL 160 ACRE
LAYOUT *B*



LAND RECLAMATION PROJECT
ORGANIZATION CHART

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Appendix E

SOCIO-ECONOMIC CHARACTERISTICS

Purpose

The costs and returns for each site are described in Appendix H. The purpose of this appendix is to provide results of studies on socio-economic characteristics of each Phase 3 site which may indicate an advantage for a particular site aside from nonmonetary aspects. A summary of socio-economic characteristics has been included for the Phase 2 site.

Summary

Primary consideration is given to the principal factors of population, farm characteristics, and land values. Results of the study on each site are summarized in Table E-1. Detailed data on each factor are presented below. Analysis of the primary socio-economic characteristics in Table E-1 are highlighted as follow:

Population

There appears to be no significant difference between the sites in the number of people residing within the site boundaries. However, there are significantly fewer people residing within three miles of the Essex site. This indicates that fewer people would be influenced by use of the Essex site. The greatest number of people live within three miles of the St. Anne site, which is located near the city of Kankakee.

Farm Characteristics

The amount of land that is presently idle or is not extensively used is highest in the Essex site. Present production from the site is low due to poor sandy soils. Therefore, the potential for agricultural improvement by irrigation and sludge application would be the greatest and opposition to the project by local residents would also likely be the least.

Table E-1

SUMMARY OF SOCIO-ECONOMIC CHARACTERISTICS

<u>Item</u>	<u>Phase 3 Sites</u>			
	<u>Coal City</u>	<u>Essex</u>	<u>St. Anne</u>	<u>Andres</u>
<u>Population (1960)</u>				
Within Sites	314	354	325	307
Within 3 Miles of Sites	4500	2340	6070	3020
<u>Farm Characteristics (1966-67)</u>				
Idle Land - %	12	26	21	10
Dwelling Units - No.	95	100	90	86
Land Owners - No.	134	152	123	164
Ave. Area Owned - Acres	142	129	149	126
Farm Operators - No.	95	100	90	86
Ave. Area Farmed - Acres	248	242	256	292
Full Owner Operators - %	44	37	28	44
Part Owner Operators - %	20	22	21	20
Tenants - %	36	41	51	36
<u>Land Value, Based On</u>				
Assessed Value ^{1/} (\$)	644	406	517	732
Land Productivity (\$)	597	400	426	770
Recent Sales (\$)	494-803	250-425	170-600	-
Highway Purchases (\$)	-	-	-	700
Value Used (\$)	600	400	425	775

1/ Includes value of farm improvements and land.

The sandy lands, characteristic of Essex and St. Anne sites, should be the easiest to purchase because of the higher percentage of idle land and the low production under present and projected without project conditions.

There are relatively small differences between the sites in number of dwellings, size of ownership, and ownership patterns. However, the percent of tenancy is highest on the Essex and St. Anne sites. This is expected to contribute to the ease in purchasing the land, and also in leasing the land back to the tenants after completion of the project.

Land Values

Land and improvement values, compiled by four methods, are lowest for the Essex site and highest for the Andres site. The Essex site would be the least expensive to purchase and yet would provide the largest potential for agricultural improvement and economic impact on surrounding communities.

The assessed value of land and improvements is lowest on the Essex site and highest on the Andres site. With project development, increased property taxes and other indirect benefits would be greatest from the Essex site.

Comparisons of other advantages and disadvantages of each site are summarized in the main report.

Sources of Data

Principal sources of data for this study were U.S. Census Reports for 1940, 1950, and 1960, Chambers of Commerce, County Offices, Illinois Crop Reporting Service, the University of Illinois and city officials. Reconnaissance of each site was made by agricultural specialists and numerous interviews were obtained from local farmers, agricultural leaders, businessmen, and local government officials. Descriptive data on each site were obtained from ground reconnaissance and study of aerial photographs and maps

General Description

Coal City Site

The Coal City site is located entirely in Grundy County. The small town of Coal City, which contained 2,852 people in 1960, lies adjacent to the northeast boundary of the site. Braceville, which had 558 Persons in 1960, is located near the southeast site boundary.

Grundy County land use plans showed about 15 single non-farm houses located within about one mile of Coal City but inside the site boundary. Four non-farm houses are located within one mile of Braceville and within the site boundary. In addition, the small town of Central City, which contained 30 people in 1960, is located entirely within the site and within one mile of Braceville. Most houses in this village appear to be somewhat deteriorated. All other houses within the site boundaries are farm homes with the exception of a few recently constructed single family homes on Highway 9 leading into Braceville. A 40-acre private open space near Coal City is also within the site boundary.

Essex Site

The Essex site, located partly in Will and Kankakee Counties, has two population centers near the site area; i. e. Custer Park located along the northern boundary and Essex located about one mile from the southwestern boundary. The population of Custer Park was not listed in the 1960 census but probably does not exceed 200 people. Essex had a population in 1960 of 328.

St. Anne Site

The St. Anne site, located partly in Iroquois and Kankakee Counties, has several villages located within two miles of the site

boundary but none within the area. From observation, there appears to be more wooded area interspersed with farming land in this site than in any of the other sites. This site contains the Cote Farms Inc. which appears to be the most prosperous farm observed during the reconnaissance.

Andres Site

The village of Manteno, with a population in 1960 of 2,225, is located within about one mile of the eastern boundary of this site. A number of recently constructed single family non-farm houses, along Highway 9 and south along Highway 30, are located within the site boundary. Other homes in the area appear to be mostly single family farm dwellings.

Population

County Population

Population estimates for 1940, 1950, 1960, and 1967 for Grundy, Kankakee, Will, and Iroquois Counties are given on Exhibit E-1. These data show that Will County has the largest population and has had the highest growth rate during the past 27 years. Iroquois County has had the lowest growth rate.

The number of farm and non-farm people living in rural areas of the counties is given on Exhibit E-1. Non-farm people constitute 85 percent of the people living in the rural areas of Kankakee and Will Counties, and over 60 percent in Grundy and Iroquois Counties.

Population of major cities in each county for the past three decades are given on Exhibit E-1.

Estimates of the total population within townships of the selected study sites are summarized on Exhibit E-1. Of the four sites, the least number of people reside within the Essex site boundary and the most reside in the St. Anne site.

Site Population

Estimates of the number of farm dwellings and farm people within each site are given on Exhibit E-2. These estimates were prepared from counts of the number of households listed in the County Recorder Plat Books, and the average number of persons per household published in Annual Farm Census reports.

Although differences in the characteristics between the sites are small, the number of farm dwellings and farm people, and the density of population per square mile are greatest for the Essex site.

Employment

Employments conditions in 1960 for each county are given in Table E-2. Fewer people are employed in agriculture than any other major industry in Grundy, Kankakee and Will counties and agriculture rates next to last among major industries in Iroquois County.

Table E-2

TOTAL EMPLOYED IN MAJOR INDUSTRIES BY COUNTY, 1960^{1/}

County	Total Em- ployed No.	Employed in Service/ Industries		Employed in Manufact- uring		Employed in Agriculture		Employed in all other Industries	
		No.	%	No.	%	No.	%	No.	%
Grundy	8,165	3,400	41.6	2,843	34.8	1,152	14.1	770	9.5
Kankakee	30,484	16,582	54.4	9,996	32.8	2,281	7.3	1,675	5.5
Will	67,319	36,146	53.7	24,363	36.1	2,296	3.4	4,514	6.8
Iroquois	12,835	6,174	48.1	2,685	20.9	3,318	25.8	658	5.2

^{1/} U.S. Bureau of the Census - Employment in Industry by Counties, 1960.

Income

The median income per family, employed males, and farmers and farm managers in 1960 is given in Table E-3. In general, average incomes are higher for non-farm people.

Table E-3
MEDIAN INCOME, 1960^{1/}

<u>County</u>	<u>Median Net Incomes</u>		
	<u>Family</u>	<u>Employed Males</u>	<u>Farmers and Farm Managers</u>
Grundy	\$5,879	\$4,901	\$3,372
Kankakee	6,286	4,936	3,102
Will	6,755	5,596	3,290
Iroquois	5,409	3,287	2,956

^{1/} U.S. Bureau of the Census - Median Income by Counties

Number and Size of Farms

Number and Size of Farms

The distribution of land ownership within each site is summarized on Exhibit E-3. The Andres site had the largest number of owners but the smallest average of land holding while the St. Anne site had the least numbers of owners but the largest average land holding. These averages are based on ownerships and do not reflect differences in productivity of land or cropped average.

Number and Size of Operating Units

Data for each site on number of farm operators, and average size of operations are given on Exhibit E-3. It is noted that, in the Essex site there are more farm operators and the average size operating unit is smaller than in other sites. Obviously some land outside the boundaries of the sites is farmed by some of the operators. Although there is con-

siderable variations within townships, the overall differences in these data are not significant.

The Coal City and Andres sites have the largest proportion of owner-operators. This is probably due to the more productive land and to a lower percentage of land not cropped in these areas. The proportion of part-owner operators among the sites is about equal, however, the proportion of tenant-operated farms is highest in the Essex and St. Anne sites. This indicates the general tendency for a higher proportion of better lands being operated by owners.

Idle Cropland

The estimated amount of land in each site that is idle or non-cropped is summarized on Exhibit E-3. These data are related to previous factors considered such as proportion of land classed as sandy, land tenure, size of farming units and land value. As noted, about 25 percent of the land in the Essex site and about 20 percent in the St. Anne site are non-cropped.

Land Tenure

Data on land tenure for Will and Iroquois Counties were obtained from the Illinois Crop Reporting Service. For Kankakee County, the County Recorder's Plat Book provided information on farm operators as well as on land ownerships. Land tenure data for Grundy County was assumed to be similar to that of Will County.

Data on the tenure of land for each site were extrapolated from county data. Data available for Grundy and Will Counties indicated that these data would be representative of the Coal City and Andres sites. Likewise, data available for Will and Kankakee Counties appeared representative of the Essex site, and for Kankakee and

Iroquois Counties for the St. Anne site. Land tenure estimated for each site are given on Exhibit E-3.

Value of Land and Improvements

Establishment of actual property value requires, in most instances, information that best can be obtained from competitive bidding between buyers and sellers. In absence of this information, land values can be estimated in a number of ways but in the final analysis they should be based on the fair cash value at their highest and best use at the time of transfer in ownership.

For this study, four methods of evaluation were used for predicting realistic values per acre for each alternative site. These methods included assessed value for tax purposes, productivity value, actual sales, and condemnation value. The results are shown on Table E 4.

Assessed Value

The assessed value of land and other real property is based on 1963 county assessed valuations. Kankakee County was reappraised in 1967. The assessed values of portions of the Essex and St. Anne sites located in Kankakee County were current. Values for the remainder of these two sites and the Coal City and Andres sites were updated to 1967 values by index figures furnished by the University of Illinois.

In Illinois, the assessed valuation of farmland and farm buildings is supposedly fixed at 55 percent of the market value. However, market values computed by this relationship result in much lower market values than actually obtained from sales transactions. Assessed values for improvements are generally closer to actual market prices because of the relative ease by which building and improvements can be appraised, and by which adjustments can be made to keep valuations current.

Table E-4

FARM VALUES
(\$ per Acre)

<u>Site</u>	<u>Recommended Values (Rounded)</u>	<u>Assessed^{1/} Value Method</u>	<u>Productivity^{2/} Value Method</u>	<u>Recent^{3/} Sales Method</u>	<u>Land^{4/} Purchase for I-57</u>
<u>Coal City Site</u>	600	644	597	-	-
Braceville Town- ship	475	513	465	494	
Maine Township	600	614	596	-	
Mazon Township	750	865	760	803	
 <u>Essex Site</u>	 400	 406	 400	 -	 -
Custer Township	350	356	356	260-425	
Essex Township	425	437	417	250	
Salina Township	500	455	491	-	
 <u>St. Anne Site</u>	 425	 517	 426		 -
Beaverville Town- ship	300	466	283		
Pennbroke Town- ship	500	528	497		
St. Anne Township	625	648	638	170-600	
Popineau Township	625	886	624		
 <u>Andres Site</u>	 775	 732	 770	 No Info.	 700
Wilton Township	700	659	703		
Peotone Township	825	753	815		

^{1/} 1967 assessed values from Supervisors of Assessments of the Counties.

^{2/} U. of Illinois Ag. Exp. Sta. Bulletin 707 applied to SCS production by soil types.

^{3/} Recent farm sales obtained at County Treasures Office in 3 counties.

^{4/} Right-of-way Engineer, Elgin District, Illinois Highway Division.

Based on recommendations from County Assessors, the assessed values recorded from current assessment rates for improvements were increased by two times and for land by four times to determine the current market values in the Coal City and Andres sites and for portions of the Essex and St. Anne sites. As noted earlier, the portions of Essex and St. Anne sites located in Kankakee County were adjusted proportionately to maintain uniformity for each site. A further adjustment was necessary for the Andres and the Will County part of the Essex site. Will County assessments were based on total assessed valuations only. To maintain uniformity in procedure by sites, estimates of values for improvements and land were necessary for Will County. This was done by correlating relationships between assessed valuations and market values by the number of farm ownerships for part or all of the other sites.

The average market value of land and improvements per acre established from assessed valuations are summarized in Exhibit E-4. These data show that the average value of farm property is significantly lower in the Essex site, followed by St. Anne, Coal City, and Andres.

A higher portion of farm ownerships in the Essex and Andres sites have lower market values relative to assessed value, while the opposite occurs for the Coal City and St. Anne sites

Productivity Value

Procedures for establishing farm land values by soil productivity ratings are outlined by the University of Illinois^{1/}. Though soil product-

^{1/} Condemnation, Land Value, and Severance Damage on Farmland, Bulletin 707, University of Illinois Agricultural Experiment Station, 1965.

ivity rating is the principal variable in this method, four additional variables associated with the price of land per acre considered are (a) the average building assessment per acre, (b) average number of areas sold per year, (c) population change, and (d) percentage of non-cropland. These variables either add to or subtract from the value of land, based upon productivity rating.

Data in Bulletin 707 is based on the bench-year 1954, with percentage increases in land value provided up to 1959. These data were up-dated by percentage changes to 1967. To determine the current value per acre for each site the following procedure was used:

- (a) Determination of the value zone of townships within each site.
- (b) Determination of the average soil productivity rating for each township. (Obtained from soil reports by SCS and the University of Illinois Agricultural Experiment Station.)
- (c) Given the soil productivity rating, determination of the price per acre associated with that rating from the schedule of appropriate value zone table (Bulletin 707).
- (d) Adjustment by approximate factors for the effects of the four variables influencing land values as noted above.
- (e) Adjust upward the established base price per acre for each township for the bench-mark year of 1954 to current values for 1967.

Soil productivity ratings, based on corn for grain compiled for each site are shown on Exhibit E-5. Market values, adjusted to 1967, as developed from the assessed values and soil productivity ratings are summarized on Exhibit E-6.

Farmland Sales

Recent farm sales were available for only three of the counties where sites are located. Few sales have occurred recently and there were wide variation in the sales price per acre. This reflects wide differences in the quantity and quality of land and the improvements associated with each sale. However, the limited data obtained does indicate a similar magnitude and pattern in the value of land and improvements determined by the alternative methods. (Table E-4).

Condemnation Value

A good example of the average value of land determined by recent purchase of right-of-way was available for the Andres site. As obtained from the Elgin District of the Illinois Highway Division, the condemnation value in this site averaged \$700 per acre which is essentially the same value as estimated by alternative methods in this study.

Recommended Value

Table E-4 summarizes per acre values established by the various methods for land and buildings in each site. These data show a close correlation between results by the four methods. Average value per acre is lowest for the Essex site, followed by the St. Anne and Coal City with the highest value in the Andres site.

Table E-4 shows also the values used in the study to estimate the probable purchase costs of each site. These values are rounded from values computed by the various methods.

Characteristics of Tinley Park Site

Principal socio-economic characteristics of the Tinley Park (Phase 2) site are summarized as follows:

Population

The number of people residing within the site boundary is estimated at around 60 of which about 55 are dependent directly on farming for their livelihood.

Farm Characteristics

Principal farm characteristics, as reported by Cook County records, are presented below. County records indicated a high percent of unimproved or idle land, but observation of land use in the area indicated that this value may be high and therefore needs verification.

Percent of idle land	45
Number of dwelling units	14
Number of land owners	16
Average size of ownership	108 acres
Number of farm operators	10
Average size of operatorship	172 acres
Percent of full owner operators	60
Percent of part owner operators	10
Percent of tenants	30

Land Values

Estimated market value of land, computed from average assessed values, amounted to about \$900 per acre. However, data on recent sales for forest preserve purposes indicated land values at about \$2,200 per acre. This value was used to estimate land purchase costs for the Tinley Park site.

County Population					Township Population		
County	1940 ^{1/}	1950 ^{1/}	1960 ^{1/}	1967 ^{2/}	Annual Increase (%)	Site	County and Townships
Grundy	18,398	19,217	22,350	25,000	1.33	Coal City	Grundy County
Kankakee	60,877	73,524	92,063	100,300	1.46		Maine
Will	114,210	134,336	191,617	232,000	1.81		Braceville
Iroquois	32,496	32,348	33,562	33,800	0.15		Mazon
							Total
							3792
							4504
Rural Population							
County	Non-farm		Farm		Total		
	Number	Percent	Number	Percent			
Grundy	7,244	63	4,319	37	11,563		Essex
Kankakee	39,885	85	6,948	15	46,833		Kankakee County
Will	47,379	85	8,673	15	56,052		Salina
Iroquois	17,323	61	11,020	39	28,343		Essex
							788
							744
							795
							Will County
							Custer
							611
							2143
							2341
							Total
							2370
							2871
							832
							6073
							630
							2392
							3022
							Total
							558
							1982
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							6073
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EXHIBIT E-2

<u>Site</u>	<u>County and Township</u>	<u>No. of Farm Dwelling Units</u> ^{1/}	<u>Persons per Unit</u> ^{2/}	<u>Total Farm People</u>	<u>Farm Population Density/sq.mi.</u>
Coal City	Grundy				
	Mazon	17	3.8	65	
	Maine	47	3.0	141	
	Braceville	<u>31</u>	<u>3.5</u>	<u>108</u>	
	Total	95		314	10
Essex	Kankakee				
	Essex	22	3.5	777	
	Salina	40	3.6	144	
	Will				
	Custer	<u>38</u>	<u>3.5</u>	<u>133</u>	
	Total	100		354	11
St. Anne	Kankakee				
	St. Anne	12	3.5	42	
	Pembroke	23	3.7	85	
	Iroquois				
	Beaverville	<u>55</u> ^{3/}	<u>3.6</u>	<u>198</u>	
	Total	90		325	10
Andres	Will				
	Wilton	54	3.6	189	
	Peotone	<u>32</u>	<u>3.7</u>	<u>118</u>	
	Total	86		307	10

^{1/} County Plat Books^{2/} Illinois Annual Farm Census^{3/} Includes three units in Papineau Township

LAND RECLAMATION PROJECT
PHASE 3
SITE POPULATION

Farm Ownership				Farm Operators			
Ownerships		Sites		County & Township	Number of Operators	Area in Farms (Acres)	Average Size of Operation (Acres)
Size Groups (Acres)	Midpoint (Acres)	Coal City	Essex				
Under 59.9	30	30	33	Grundy	17	5,718	328
60 - 99.9	80	29	35	Mazon	47	12,786	273
100 - 139.9	120	18	29	Maine	31	5,038	163
140 - 179.9	160	24	27	Braceville	95	23,542	248
180 - 219.9	200	10	9	Total			
220 - 259.9	240	7	8	Kankakee	22	4,707	216
260 - 299.9	280	3	4	Essex	40	8,028	203
300 - 339.9	320	6	2	Salina			
340 - and over		17	5	Will			
Total Acres		19,016	19,659	Custer	38	11,510	301
Total Farms		134	152	Total	100	24,245	242
Average Size of Farm		142	129	Kankakee	12	3,125	269
				St. Anne	23	2,878	124
				Pembroke			
				Iroquois	55	17,075	307
				Beaverville	90	23,078	256
				Total			
				Andres	54	17,219	319
				Will	32	7,338	226
				Peotone	86	24,557	291
				Total			

Idle Cropland			
Site	Proportion of Site Areas by Townships %	Idle or Non-Cropped Area %	
Coal City	42	7	
Braceville Township	46	12	
Maine Township	12	5	
Mazon Township	100	11.8	
Weighted Average			
Essex	7	19	
Essex Township	83	25	
Salina Township	10	33	
Custer Township	100	25.6	
Weighted Average			
St. Anne	60	32	
Beaverville Township	5	5	
Popineau Township	24	5	
St. Anne Township	11	5	
Pembroke Township	100	21.2	
Weighted Average			
Andres	40	6	
Peotone Township	60	13	
Wilton Township	100	10.2	
Weighted Average			

Land Tenure			
County and Site	Full Owner Operators (%)		Tenants (%)
	Operators (%)	Part Owner Operators (%)	
Grundy County (Coal City Site)	44.4	20.2	35.4
Will County (Andres Site)	44.4	20.2	35.4
Essex Site	36.5	22.3	41.2
Kankakee County	30.0	24.0	46.0
St. Anne Site	27.7	21.5	50.8
Iroquois County	26.8	20.6	52.6

LAND RECLAMATION PROJECT
PHASE 3 SITES
FARM CHARACTERISTICS

Site	Farms Owned	Assessed Value						Market Value over Assessed Value
		Improvements		Land		Total		
		Amount	Percent	Amount	Percent	Amount	Percent	
Coal City	134	\$661,780	21.2	\$2,461,910	78.8	\$3,123,690	100.0	3.58
St. Anne	122	278,340	12.2	2,007,665	87.8	2,286,005	100.0	3.46
Beaverville & Papineau T.	-	168,340	12.3	1,204,430	87.7	1,372,770	100.0	
St. Anne & Pembroke T.	-	110,000	12.1	803,235	87.9	913,235	100.0	
Essex	152	537,612	24.8	1,635,133	75.2	2,172,745	100.0	3.06
Essex & Salina T.	-	164,425	12.5	1,154,345	87.5	1,318,770	100.0	
Custer T.	-	373,187 ^{1/2}	43.7	480,788 ^{1/2}	56.3	835,975	100.0	
Andres	164	1,788,333 ^{1/2}	43.7	2,303,962 ^{1/2}	56.3	4,092,295	100.0	3.10

^{1/2} Extrapolated from farms owned and percent of assessed value.

Townships and Sites	Assessed Value Acres	Market Value/ac
Braceville	5805	\$513
Maine	10750	614
Mazon	4945	865
Total Coal City	21500	644
Salina	7095	\$455
Essex	4515	437
Willco - Custer	9890	356
Total Essex	21500	406
Iroquois County		
Beaverville	14190	\$466
Papineau	645	886
Kankakee County		
St. Anne	3440	645
Pembroke	3225	538
Total St. Anne	21500	517
Wilton	6235	\$659
Peotone	15265	753
Total Andres	21500	732

EXHIBIT E-4

LAND RECLAMATION PROJECT
LAND VALUE BASED
ON ASSESSED VALUE

Soil Types	Coal City				Essex Site				St. Anne Site				Andres Site			
	% of Area	Bu. per Acre	Prod. 1/ Rating		% of Area	Bu. per Acre	Prod. 1/ Rating		% of Area	Bu. per Acre	Prod. 1/ Rating		% of Area	Bu. per Acre	Prod. 1/ Rating	
Sands	7	1505	57	47.5	38	8170	57	47.5	60	12900	57	47.5	-	-	-	-
Sandy Loams	79	16985	83	69.0	42	9030	74	61.7	5	1075	74	61.7	-	-	-	-
Silty Clay Loams	3	645	83	69.0	10	2150	87 ^{2/}	72.5	24	5160	78	65.0	40	8600	80	66.7
Silt Loams and Loams	10	2150	97	81	10	2150	87 ^{2/}	72.5	11	2365	94	78.0	60	12900	92	76.7
Mine Dumps	1	215	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	100	21500			100	21500			100	21500			100	21500		

^{1/} Based on 120 bushels of corn/acre = 100

^{2/} Weighted from 88 and 83 bushels for silty clay loams and silt loams and loams respectively.

LAND RECLAMATION PROJECT
LAND PRODUCTIVITY RATINGS

**LAND RECLAMATION PROJECT
LAND VALUE BASED
ON PRODUCTIVITY RATINGS**

Site	Soil Type	% of Area	Acres	Ave. Corn Yield	Productivity 120 Bu. = 100%	Average Bldg. Assessment	Building Assessment Rate	Land not Cropped %	Rate Amount	Base Value 1954	Net Change in 2 Base Value 1954	New Base Value 1954	Increase in Value		Value / Acre November 1966	
													at 21.6%	at 5%		
ST. ANNE	Beaumontville T. Sands	60	12,900	57	47.5	16	1.98	32	-1.96	-63	315	284	61	14	57	416
	Pembroke T. Sandy Loams	5	1,075	74	61.7	13	1.98	26	-1.96	-10	341	357	77	18	71	523
	St. Anne T. Silty Clay Loams	24	5,160	78	65	34	1.98	67	-1.96	-10	401	458	99	23	92	672
	Popineau T. Silt Loams and Loams	11	2,365	94	78	17	1.98	38	-1.96	-10	420	448	97	22	90	657
	Totals & wt. Ave.	100	21,500													

Summary:

Adjusted Value/Acre		Adj.	
Value	Cropped Acres	Value	Acres
12,900	416	3,650,700	283
1,075	523	534,275	497
5,160	672	3,292,080	638
2,365	657	1,675,760	624
21,500		9,152,815	426

Beaumontville	Sands	40	8,600	80	66.7	92	1.76	162	13	-1.09	-14	403	418	551	119	28	110	808
Pembroke	Sandy Loams	60	12,900	92	76.7	102	1.76	180	5.5	-1.09	-6	414	414	588	127	29	118	862
St. Anne	Silty Clay & Loams																	
Popineau	Silt Loams & Loams																	
Totals & Ave.																		

ANDRES

Wilton T.	Silty Clay Loams	40	8,600	80	66.7	92	1.76	162	13	-1.09	-14	403	418	551	119	28	110	808
Pestone T.	Silt Loams and Loams	60	12,900	92	76.7	102	1.76	180	5.5	-1.09	-6	414	414	588	127	29	118	862

Summary:

Adjusted Value/Acre		Adj.	
Value	Cropped Acres	Value	Acres
8,600	808	6,045,800	703
12,900	862	10,513,500	815
21,500		16,559,300	

Wilton	Silty Clay Loams	40	8,600	80	66.7	92	1.76	162	13	-1.09	-14	403	418	551	119	28	110	808
Pestone	Silt Loam & Loams	60	12,900	92	76.7	102	1.76	180	5.5	-1.09	-6	414	414	588	127	29	118	862
Totals & Ave.																		

LAND RECLAMATION PROJECT
LAND VALUE BASED
ON PRODUCTIVITY RATING

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Appendix F

ENVIRONMENTAL CONSIDERATIONS

Introduction

The conservation and improvement of the quality of the existing environment at the reclamation site is of prime concern to this project. In the past, there have been many instances in which the lack of such concern has resulted in the gradual degradation of environmental conditions. Poorly planned waste disposal is undoubtedly one of these instances. In this project, consideration is given to possible effects on the environment influenced by the distribution of sludge on the land. Care has been taken so that there will be a minimum of adverse changes in environmental quality as a result of the project.

The disposal of large quantities of sludge by land reclamation and agricultural development will result in changes in the general environmental character of the area. These changes may be broadly classified into (a) those that will affect the inhabitants of the area, and (b) those that will affect the natural resources of the area.

This Appendix is directed mainly to the environmental aspects of Phase 3 site, because of its relatively large area. The Phase 2 site will not have the potential for wildlife enhancement nor the increased crop returns that will accrue to the Phase 3 site; however, ground water hazards will be less.

Effects on Inhabitants

Operation of the project will cause several changes in environmental conditions that will benefit the inhabitants of that area. These

changes of the social and economic environment are discussed in Appendix E, but they include the up-grading of soil productivity, increased economic input to the area, and an improved water supply. Large quantities of water, organic matter, and plant nutrients will be added to the soil as a result of the application of digested sludge. The sludge addition and accompanying irrigation will improve the characteristics of the soil from its present state of marginal productivity to a highly productive state. Crop yield increases will substantially add to the general economy of the area. Improved soil productivity will increase the agricultural land tax base for the county. Phase 3 will include a public water supply system which will improve the capacity and reliability over the present individual farmstead supplies. It also will eliminate reliance on the existing ground-water supplies.

Pathogens

The proposed land reclamation plan includes provisions to minimize or prevent potential health hazards. An extensive review of existing literature was conducted to evaluate the effects of the proposed method of sludge farming. However, none of the references provide sufficient basis to predict the effects of this project. Therefore, it is recommended that the operational program include provisions for medical examinations, immunizations and other appropriate public health measures for all site personnel.

Sludge digestion reduces the number of disease-producing bacteria and viruses contained in raw sewage sludge but will not completely eliminate them. Investigations have shown that the activated sludge process inactivates viruses by an adsorptive phenomenon which forms a stable sludge-virus complex.^{1/} However, the fate of viruses within this complex has not been determined. Heating is an effective means for

^{1/} "Human Enteric Viruses in Sewage," N. Clarke and P. Kabler, Health Laboratory Science, January 1964.

destroying viruses. Table I indicates some of the viruses most frequently found in raw sewage and the time required for 99.9 percent reduction when heated to about 82°F.

Table F-1

TIME AT 28°C FOR 99.9 PERCENT REDUCTION OF THE
INDICATED VIRUS IN RAW SEWAGE

<u>Virus</u>		<u>Time</u>
Poliovirus	I	17 days
ECHO	7	28 days
ECHO	12	20 days
Coxsackie	A9	6 days

Since Chicago's raw sludge is digested at 95°F for an average of 15 to 20 days, it is likely that some viruses may be present in the digested sludge.

Sprinkler application of the sludge will result in a dispersion of the sludge in the atmosphere for a short period of time. Field investigations using sewage effluent for spray irrigation show that coliform organisms are air-borne only within moisture droplets.^{1/} Thus, if contact with the sprinkler mist is avoided, there should be little danger of air-borne disease exposure. There is further evidence that sludge-borne pathogenic organisms are not liberated in atmospheric dispersions,

^{1/} "Study of Waste Water Reclamation and Utilization," State Water Pollution Control Board, Sacramento, Calif., Publication No. 18, 1957.

since there is no greater incidence of illness among workers in sewage treatment plants, ^{1/} who encounter aerosols from aeration tanks.

The fate of coliform bacteria and pathogenic organisms applied to soil and crops has been investigated. Results of tests conducted on tomatoes and lettuce showed that if raw sewage irrigation was stopped 35 days before harvesting, no public health problem existed. ^{2/} Most regulations pertaining to the use of sludge as a fertilizer require that it be applied only to crops which grow above ground level or that it be disinfected, after which it can be used safely under all conditions. A typical example of these regulations are those adopted by the California Department of Public Health. ^{3/} These regulations state, in part, that:

"No sludge . . . shall be distributed or used for fertilizing any growing vegetables, garden truck or low growing fruits or berries, unless the sludge . . . shall have been rendered innocuous and free of danger of spreading disease by such measures as (a) kiln drying, (b) bed drying or aging in storage, and in either case for no less than 30 days, (c) conditioning or treating to the satisfaction of the State Department of Public Health, (d) digestion to a point where the sludge . . . is practically odorless, drains readily, and not over 50 percent of the total solid matter is in the volatile form."

^{1/} G. Stein, Personal Communication.

^{2/} "Contamination of Vegetables Grown on Polluted Soil," W. Rudolfs, L. Falk, and R. Ragotzkie, Sewage and Industrial Wastes, Vol. 23, 1951.

^{3/} "Regulations of Use of Sewage for Irrigating Crops," Special Bulletin No. 59, State of California, Department of Public Health, May 27, 1933.

Analyses of sludge from the Sanitary District indicate that the volatile matter is normally above 50 percent at the present, and that the sludge dewateres slowly but is practically odorless. Increased digester capacity coupled with sludge thickening should consistently produce sludge containing less than 50 percent volatile matter.

Other studies have shown that continuous and complete virus retention or death is effected when waste water is filtered at a slow rate through 2 to 4 feet of sand or sandy loam soil. ^{1,2/} The inactivation of viruses in the soil is quite rapid since the viruses cannot multiply away from living cell hosts.

Investigations being conducted by the Agronomy Department of the University of Illinois should provide an adequate basis for the design of public health protective measures. These studies will determine the viable pathogens in the digested sludge, their longevity in soils under various environmental conditions, and their rate and distance of movement with the water in soils. The possibility of contaminating the ground-water with pathogenic organisms is expected to be very small.

The Sanitary District is currently sponsoring a study to determine the feasibility of disinfecting sludge by radiation. Another possibility would be to heat the sludge sufficiently to kill the pathogenic bacteria and viruses. This would require heating the sludge to a temperature of 160°F and maintaining that temperature for 30 minutes.

1/ "Effectiveness of Water Treatment Processes in Virus Removal," G. Robeck, N. Clarke, and K. Dostal, Journal AWWA, Vol. 54, No. 10, October 1962.

2/ "Digested Sewage Sludge for Soil Improvement," H. Lunt, Connecticut Express Station Bulletin 622, 1959.

Dissolved Minerals

The relationships between sludge and soil, Appendix C, have been studied. These studies suggest that the only apparent hazard to the environment from dissolved minerals would be from the nutrient minerals, particularly nitrogen, and that this hazard would be minimal for fine textured soils, such as on the Phase 2 site.

Nitrogen Effects. Since too little soil nitrogen may inhibit plant growth and too much may pollute ground waters it is desirable to balance the quantities of nitrogen in the system. Nitrogen is added to the soil from rainfall and the decomposition of crop roots, stalks and leaves, by bacteria in the soil and through fertilizers.

Nitrogen is removed from the soil in three ways: gas formation, crop removal, and leaching. An amount of nitrogen is lost by ammonia volatilization when the sludge is applied to the land. Other gaseous losses occur through the denitrification process within the soil. Crop development by plants also removes nitrogen from the soil, although a portion of this nitrogen is returned to the soil with the crop residue after harvesting. Excess soluble nitrogen is leached to the ground-water.

An approximate nitrogen balance has been estimated to account for the nitrogen added to the soil. A determination of the nitrogen leaching to the ground-water is especially important since large concentrations create a public health problem. Nitrogen, as nitrate, is dangerous to infants in concentrations greater than 45 ppm. Methemoglobinemia may result if infants consume water of high nitrate content. Therefore, careful monitoring of the project ground-water is necessary to insure that no public health problem will develop.

Plants, like all organisms, require nitrogen for their growth and reproduction. Nitrogen is a constituent of all proteins, all enzymes, and many metabolic intermediates involved in synthesis and energy transfer. Of the fifteen elements known to be needed for higher plants, nitrogen is the most necessary of those that come from the soil on the basis of relative number of atoms needed.^{1/} Plants utilize nitrogen in solution.

Form of Nitrogen. Much of the nitrogen added to, or present in, the soil is bound to stable organic compounds. Nitrogen in this form slowly converts to nitrate, is unavailable for crop use, and presents no immediate public health problem. However, nitrogen in the ammonia form is readily oxidized to nitrate. About one third of the nitrogen in sludge is in the ammonia form and about two thirds in organic compounds. If the organic nitrogen fraction is converted to nitrate at a fixed rate, the amount of nitrate produced by the decomposition of organic compound will increase each year.

Thus, a limiting level of organic nitrogen might be reached at which level the conversion to soluble forms would satisfy all crop needs. However, this would not necessarily guarantee the conversion at an opportune time for crop useage, and the excess nitrate produced might be leached to the ground-water.

^{1/} Soil Agronomy Series No. 10 (1965), Chapter 14.

Nitrogen Input to Farms. The nitrogen inputs to the land reclamation project have been evaluated to determine an optimum sludge loading rate.

Nitrogen exists in the atmosphere as inorganic gases and in organic form as bacterial cells and dust. The organic form is considered to be negligible. Experiment by Schrines and Browns have found that the inorganic nitrogen in rain averaged 6.1 pounds per acre annually, 75.8 percent being in an available form. ^{1/}

The nitrogen returned to the soil in the form of crop residue furnishes a large portion of the nitrogen taken up by the crop. However, about 80 percent of this nitrogen is in an unavailable form. ^{1/}

The greatest external source of nitrogen is contained in the sludge. A chemical analysis of the sludge shows total nitrogen concentration of 1,700 ppm. Of the total nitrogen, 600 ppm are in the form of ammonia nitrogen. The remaining 1,100 ppm are in stable organic compounds. ^{2/}

The nitrogen inputs to the land reclamation project have been evaluated to determine an optimum sludge loading rate.

^{1/} I bid, Chapter 16.

^{2/} Appendix A. This Report.

A sandy soil is considered to be the soil reservoir for this study. The depth of the reservoir is limited to the crop root zone depth of 30 inches. Hagener Loamy Sand was chosen as the representative soil. This soil contains 3,300 pounds of organic nitrogen per acre to a depth of 30 inches. ^{1/} Of this nitrogen, 2 percent per year, or 66 pounds, is converted into available form. ^{2/}

Removal of Nitrogen From Farms. Nitrogen may be lost from soils in the forms of ammonia, elemental nitrogen, and as oxides of nitrogen. The amount lost depends upon the soil type, pH, type of crop grown, and climatic effects. About 25 percent of the added available nitrogen will be lost as gaseous products of the denitrification and ammonia volatilization processes.

The amount of nitrogen utilized by crops varies with the crop itself and with the cropping intensity. Also, the rate of nitrogen consumption increases as the rate of nitrogen application increases. ^{3/} Corn, with a yield of 140 bu/acre, was chosen as a representative crop for the study. The maximum nitrogen uptake for this cropping pattern is assumed to be 200 lb. N/acre/year. Of this, 140 lb. N/acre/year will be removed in the grain and 60 lb. /acre/year will be returned to the soil in the stover. ^{4/}

^{1/} Will County Soils, Soil Report, U. of I. Agricultural Experiment Station, December 1962.

^{2/} Soil Agronomy Series No. 10 (1965), Chapter 3.

^{3/} Agronomy Series No. 11 (1967), Chapter 23.

^{4/} Analysis of Crops Grown in Northern and Central Illinois, U. of I. Soil Report 74, June 1951.

Leaching is one of the main methods of nitrogen removal from soils. The movement of soluble nitrogen is closely related to the movement of soil water. The area near Kankakee, Illinois, will have an average ground-water through-put of 0.67 cfs/sq. mile for a sandy soil, including 0.54 as natural recharge and 0.13 as irrigation losses to deep percolation. The amount of nitrate leached will depend on many variables:

- a) form and amount of soluble and unabsorbed nitrogen present or added,
- b) rainfall,
- c) infiltration and percolation,
- d) moisture holding capacity of the soil,
- e) presence or absence of a crop,
- f) evapo-transpiration,
- g) nitrogen requirement of the crop,

Sandy soils are unable to store excess soluble nitrates. All of the available nitrogen not removed by gas formation or the crop requirement may leach to the ground-water.

Nitrogen Balance Studies. Four conditions of nitrogen application were investigated to determine the:

- a) Allowable sludge loading so that the concentration of leached NO_3 does not exceed 45 ppm, assuming that the sludge organic nitrogen remains in the soil, Exhibit F-1;

- b) Allowable sludge loading so that the concentration of leached NO_3 does not exceed 45 ppm, assuming that the sludge organic nitrogen becomes available and leaches, Exhibit F-2;
- c) The concentration of NO_3 leached to ground-water if the sludge loading is 20 tons/acre/year, assuming that the sludge organic nitrogen remains in the soil; Exhibit F-3;
- d) The concentration of NO_3 leached to ground-water if the sludge loading is 20 tons/acre/year, assuming that the sludge organic nitrogen becomes available and leaches, Exhibit F-4.

The balance estimates are very approximate. Wide differences exist in researchers estimates of nitrogen mineralization rates, crop removal potential and nitrogen retention in soils. However, the estimates suggest that the proposed annual loading rate of 20 tons per acre may be somewhat high unless all organic nitrogen is retained in the soil or greater crop removal is realized. This loading apparently could cause nitrate concentrations to increase in the leachate over about 18 years to a level above 3500 parts per million.

Future Investigations. Soil nitrogen balances have been studied for many years. Varying conditions of climate, soil, cropping patterns, ground-water, and nitrogen loading rates have made precise results difficult to obtain. Therefore, careful monitoring of conditions at the field demonstration sites is considered essential. Experiments at the University of Illinois are currently being conducted. As more information becomes available, a more precise nitrogen balance may be obtained.

Studies being conducted by the University of Illinois on the accumulation and movement of nitrogen in the soil under various sludge loadings should provide sufficient information to permit adequate design of the cropping and application systems. In addition, treatment of the runoff water could be accomplished. Several possibilities exist for treatment of drainage waters. Another solution may be the stripping of ammonia from the sludge, although the feasibility of such a method applied to sludge would have to be demonstrated.

Other problems may develop from the movement of minerals into the ground-water. While no specific hazards are apparent at this time, it is obvious that intensive monitoring will be vital for both ground and surface water supplies.

Public Water Supply

The project layouts and costs include a water supply system to serve the entire Phase 3 area. This has been considered essential because (a) existing supplies are often of doubtful quality or capacity and (b) a water system would assure protection from any potential pollution of the shallow ground-water supply.

Ground-water conditions differ at the various sites. The deep-aquifer (Cambrian-Ordovician) aquifer underlies each of the sites, but the great depth of this aquifer and overlying Maquoketa Shale assure its isolation. Shallower aquifers do not occur as a significant resource beneath the Coal City Site, because the Silurian Dolomite Unit is absent and there are no permeable-unconsolidated zones. Information is inadequate for a full evaluation of the Essex Site, but the Silurian Dolomite is absent or thin over much of the site, and permeable unconsolidated deposits seem unlikely

to be extensive. Preliminary studies indicate that the St. Anne Site may have substantial potential for ground-water development. Detailed evaluation has not been possible, but several irrigation wells are presently operating at capacities of 400 to 1,300 gpm. These wells have been completed in the Silurian Dolomite, and substantial potential may be indicated for unconsolidated deposits by the existence, through part of the area, of an apparent tributary to the buried Teay's - Valley aquifer. The Andres Site is underlain by 50 to 100 feet of clay-till deposits which should adequately protect any potential Silurian aquifer.

The shallow deposits underlying any site will be penetrated, in time, by dissolved minerals from the sludge just as they are penetrated by leeching water from farm manure, mineral-fertilizer applications or road salting. The movement of these dissolved-mineral pollutants can be confined to the project lands by subsurface and surface drains, with the possible use of drainage wells in problem areas. This drainage protection also will restrict the depth of penetration of dissolved minerals into the ground-water reservoir. The extent of this penetration probably would be sufficient to impair for some uses the ground-water beneath the site. This ground-water discharge to the drains can be treated by several methods if dissolved minerals reach concentrations which could exceed stream quality criteria; including:

- a) Reapplication to the land, by pumping from drainage detention ponds.
- b) Release to surface streams when dilution is adequate.

- c) Reduction of dissolved mineral loading by:
 - (1) Specialized treatment
 - (2) Prohibiting the discharge of certain wastes to the sewer systems
 - (3) Reducing sludge application rate
- d) Treatment of the drainage water by desalination methods.

This array of alternatives offers sufficient flexibility of approach to assure ground-water protection.

Protection is not likely to be required at the Phase 2 or Andres Sites, because of the great thickness of the underlying clay-fill. Monitoring wells are recommended, however, to verify that pollution has not occurred.

Preservation of Natural Resources

Development and operation of the project will have some effects on the natural resources of the area. Of particular concern will be its effects on the mineral, water, and wildlife resources. The effects on the soil have been described previously. Generally, these include an improvement in soil productivity, with a resultant increase in crop yield and in land value.

The extent of known mineral resources is limited to the Coal City Site where some coal deposits remain under a portion of the area.

Water Resources

Protection of water resources is vital to the success of the project. Measures for protection of the ground-water have been mentioned above. There should be few hazards to the surface water system, but project operations will have some effect on this resource also.

Surface water protection is provided by the confinement of the drainage system (ground-water discharge) described above and by isolation of storm runoff to the fields for Phase 3. Protection in Phase 2 will be accomplished by small detention reservoirs.

During periods of extremely heavy rainfall, runoff from the area could breach field embankments and wash some nitrogen, phosphorous, and various other minerals and organic material into the surface streams of the region. These minerals could contribute to algae and other aquatic-plant growth in the stream, although inherent turbidity and dilution at storm flows would reduce the hazard. During prolonged dry periods, ground-water discharge would have to be held on the site to avoid runoff which could contain amounts of nitrogen sufficient to exceed the stream-quality criteria. Some organic matter may be flushed into the drains from fields receiving a sludge application prior to a severe storm. Also, pathogenic bacteria and viruses may be carried into the streams. A concentration of bacteria conceivably could restrict body contact sports locally in the streams, but water supply systems using the stream would provide disinfection, eliminating any health hazard. This should not cause a serious health problem because recreation is minimal during storms.

If sufficient organic matter were carried to the stream to cause some oxygen depletion, the growth of fish and other aquatic life may be inhibited. A minor possibility exists also that quantities of heavy metals sufficient to cause toxicity of fish and stock or wildlife using the stream could be flushed into streams during a period of heavy rainfall. However, high flows from storm water runoff will dilute any concentration of contaminants washed off the land reclamation site.

The recommended Phase 3 plan contains certain features that will be utilized to prevent these hazards of water pollution. Perimeter ditches, field ditches, and lateral drains will confine approximately 1.5 inches of runoff within the reclamation areas. Thus, runoff from storms occurring more frequently than once in ten years would be contained on the site. Check dams will be constructed in the drainage channels and the ponds formed by these dams will provide an opportunity for settling much of the sediment and particulate matter contained in the runoff. This will remove much of the organic matter and that portion of the nitrogen and phosphorus associated with the particulate material.

Storms resulting in more than 1.5 inches of runoff will cause spills from the reclamation area, although the major portion of the runoff will be retained. The portion that is spilled will have been retained in the detention ponds for a period of time and much of the organic and particulate matter will have settled out of suspension. Also, stream-flow, turbidity and pollution loading during such a storm would be considerably higher than normal, and might conceivably be of poorer quality than runoff from the site. There would be sufficient water available during storm runoff periods for dilution of any spills from the area.

Wildlife

The sludge disposal-land reclamation project could have numerous detrimental effects on fish and wildlife in the reclamation area, although fishing potential is negligible within the proposed sites. Large quantities of organic matter that deplete the oxygen content of the streams, and

luxurious algae growths could destroy fish life in the down stream areas and heavy metals in concentrations that are toxic, could cause illness or death among wildlife using the streams for watering. However, the recommended plan contains measures for controlling or treating any polluted runoff from the reclamation area, as described above.

Thus, there should be no significant environmental changes that would be harmful to fish and wildlife in the region. Actually, the plan will provide an opportunity for enhancing wildlife production within the Phase 3 area.

This project has significant potential for providing public hunting opportunity by increasing the production of pheasant and other species of small game. The mixture of cover vegetation (hardwood trees, row crops, legumes and grassed sprinkler-operating lanes) would provide a near-ideal habitat for game-bird production. This habitat would be further enhanced by the perimeter-tree belt. Several advantages would result from this large acreage being under one management, including (a) the ability to make wide-spread modifications to game-production aspects if needed, and (b) the ability to make accessible to the public a large hunting area (largest in the state).

Conclusions

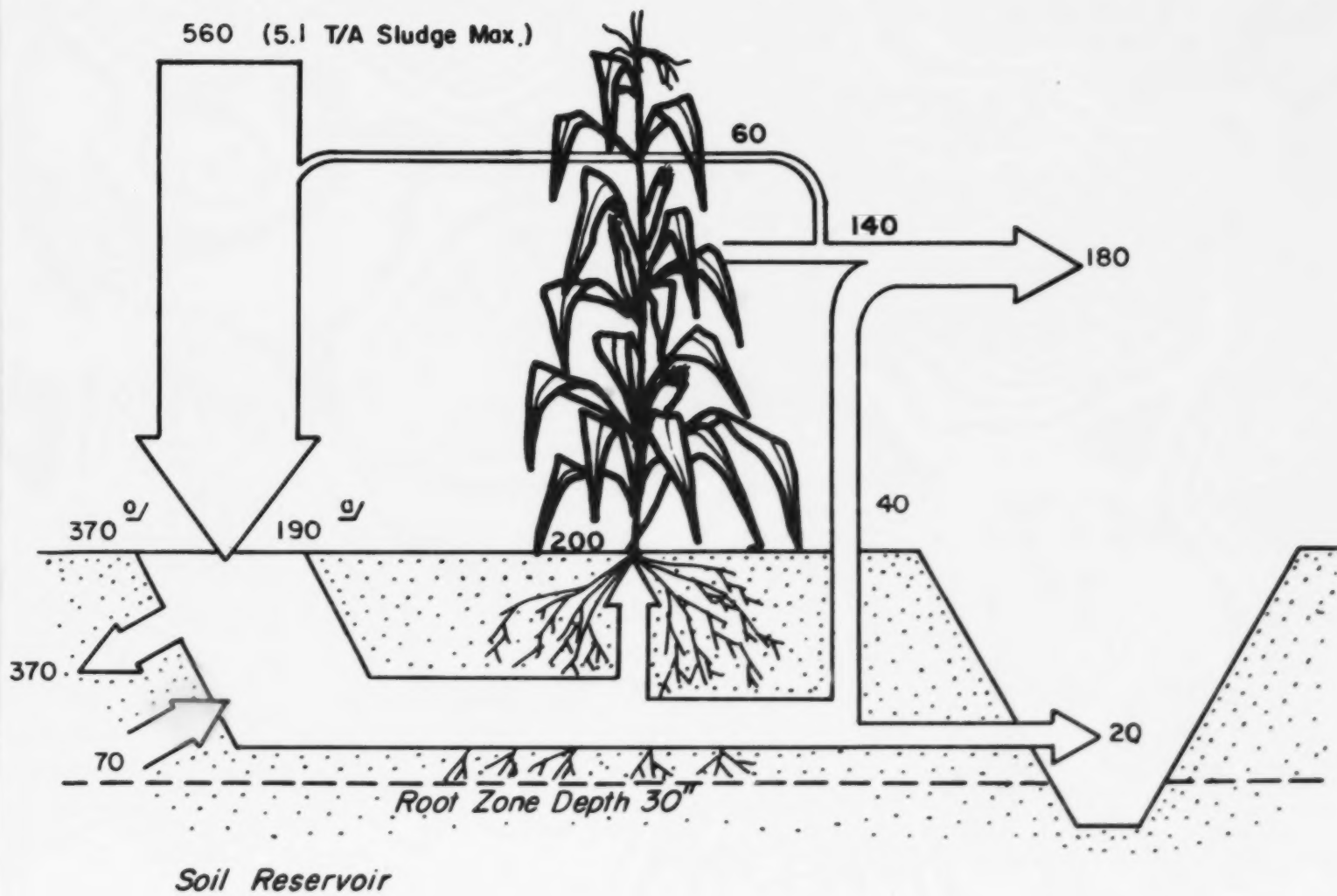
The utilization of digested sludge for land reclamation and agricultural development will result in an increase in soil productivity, with attendant increases in crop yield and land value. These effects represent social and economic changes in environmental conditions in the area that will be beneficial to the inhabitants. While there are potential

detrimental changes to the environment, particularly in the areas of public health hazards and ground and surface water contamination, there are various methods available for controlling or preventing these potential problems. These studies indicate that, with careful planning and operation of the land reclamation project, there should be no adverse changes in environmental quality of the area.

It is not possible at present to define the exact nature and magnitude of each potential problem, nor is it possible to recommend the most advantageous solution. Experiments being conducted by the University of Illinois will aid in defining the exact nature of any problems that need to be solved. Further studies should then be undertaken to develop specific solutions to any problems that could cause undesirable changes in the environment of the project area.

EXHIBIT F-1

ALLOWABLE SLUDGE LOADING ^{1/} (Assuming all organic nitrogen held)



NITROGEN BALANCE

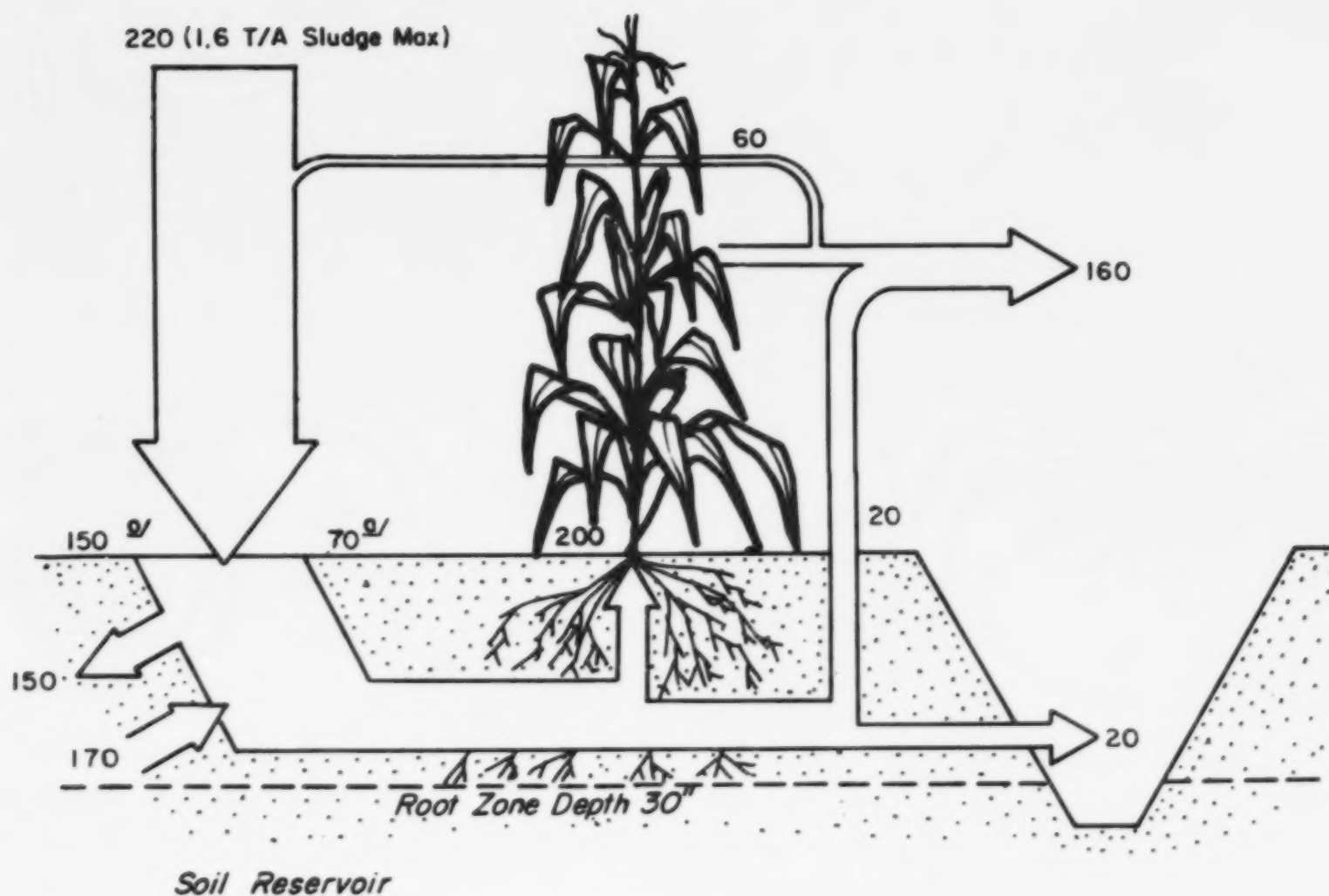
SANDY SOIL

lb./acre/year

- ^{1/} To limit the leached concentration of NO_3^- to 45 ppm
- ^{o/} Organic nitrogen
- ^{a/} Available nitrogen

EXHIBIT F-2

ALLOWABLE SLUDGE LOADING (Assuming all organic nitrogen leached)



NITROGEN BALANCE

SANDY SOIL

lb./acre/year

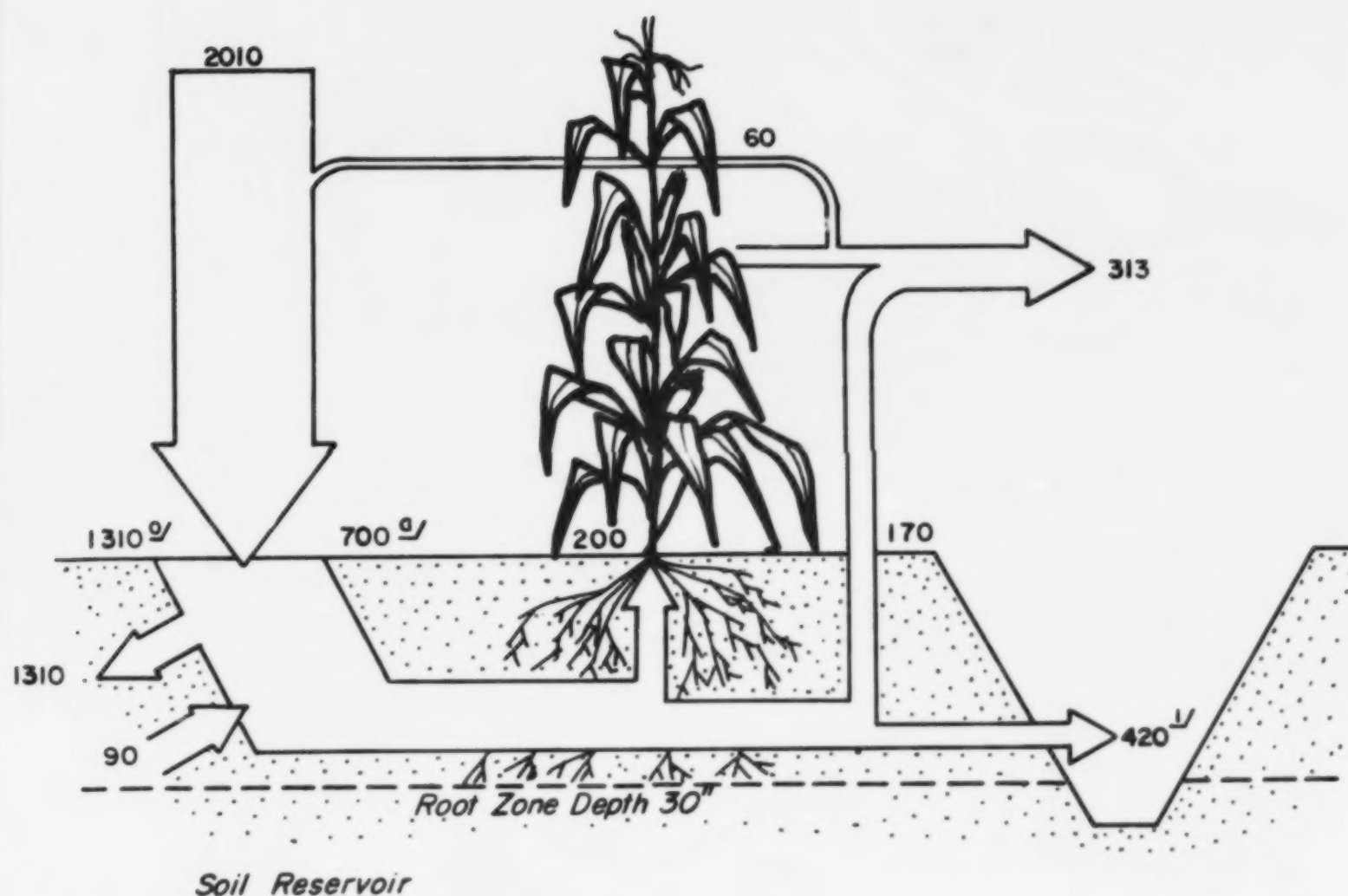
$\downarrow$ To limit the leaching concentration of NO_3^- to 45 ppm

^{o/} Organic nitrogen

^{a/} Available nitrogen

EXHIBIT F-3

SLUDGE LOADING 20 TONS / ACRE
(Assuming all organic nitrogen held)



NITROGEN BALANCE

SANDY SOIL

lb. / acre / year

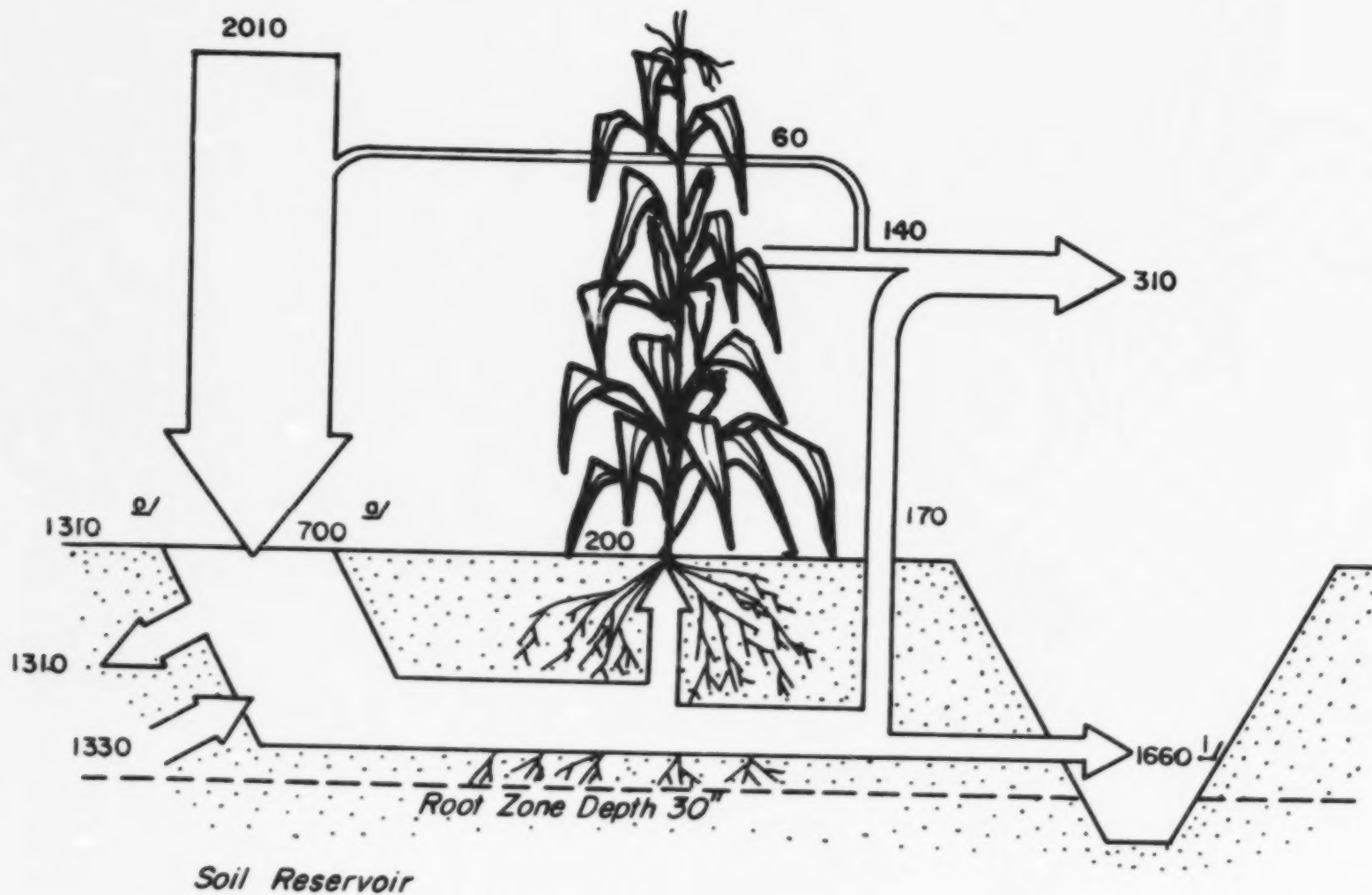
$\downarrow$ Concentration of leached $\text{NO}_3^- = 900 \text{ ppm}$

$\circ$ Organic nitrogen

$\square$ Available nitrogen

EXHIBIT F-4

SLUDGE LOADING 20 TONS/ACRE
(Assuming all organic nitrogen leached)



NITROGEN BALANCE

SANDY SOIL

lb./acre/year

- $\downarrow$ Concentration of leached $\text{NO}_3^- = 3560 \text{ ppm}$
- $\swarrow$ Organic nitrogen
- $\searrow$ Available nitrogen

Appendix G

ROUTE SELECTION AND SLUDGE CONVEYANCE

Introduction

Selection of a route for the conveyance of sludge to the land reclamation site requires an evaluation of potential conveyance methods and a selection of one of the methods. Although the Sanitary District had concluded that a pipeline would be best suited, an evaluation of other methods also was requested. To determine the capacity of conveyance system elements it has been necessary to project the weight and quantity of sludge that will be transported.

Phase 2 Site

Conveyance alternatives to the Phase 2 Site are limited, because the Sanitary District wishes to begin operations during 1968. Preliminary analysis indicates that advance construction of the Phase 3 pipeline would probably provide the most economical conveyance method to the Phase 2 Site. However, pipeline sizing and operations present difficulty in this event, and it is desirable to defer this decision to allow time for further study of other conveyance alternatives to the Phase 3 Site. Trucking will be required in order to begin early operations, because pipeline construction would require about one year. Trucking could be continued during 1969, however, the utilization rate proposed in Chapter II would require nearly 100 truck movements daily during 1970 and 1971. It, therefore, seems desirable to reach a decision about conveyance at a date which would permit a pipeline to be installed by 1970, if that method is selected.

Conveyance Capacity Requirements

Sludge Output Quantities

Sludge quantities involve two variables pertinent to conveyance studies; weight and volume. The output of treated sludge at the Sanitary District is expressed as tons of dry solids. The weight of dry solids output will continue to increase with population increases and increased use of garbage grinders. The solids weight could decrease if improved digestion removes more of the volatile solids present in the untreated sludge. The population and garbage grinding effect have been included in forecasts of untreated sludge input prepared for the Sanitary District by Greeley and Hansen.^{1/} Volatile solids reductions have been assumed to continue at the rates shown in recent operating records of the Sanitary District. The output weight has been estimated on these bases, as shown on Exhibit G-1.

The volume that a given weight of dry solids will represent depends on the concentration of the solids in the sludge. The studies for this report have been based on the planning criteria set by the Sanitary District, which include the assumption of a concentration of 3.5 percent solids. On this basis, the conveyance requirement for a pipeline would increase from 8.0 cubic feet per second (cfs) in 1972 to 11.9 cfs in the year 2015, as shown on Exhibit G-2. The sludge conveyance requirements are in terms of digested output from the Calumet and West-Southwest (WSW) Plants, where volatile solids reductions are based on the use of Imhoff tanks and heated digesters (Appendix A).

^{1/} Greeley and Hansen, Consulting Engineers, Reports on Sludge Disposal, Volume V, Parts 1 and 2, 1966.

Conveyance capacity may be necessary also to evacuate the sludge now stored in lagoons, although this requirement has not been included in these studies. Future investigations should include an evaluation of the feasibility and economics for the possibility of (a) leaving the lagoon sludge in place to permit an early sale of this property, compared to (b) evacuating the lagoons at greater conveyance cost and deferring the return to the Sanitary District from the land sale.

Conveyance capacity requirements during initial Phase 2 operations (1970 and 1971) will be dictated by the sludge output in excess of drying beds and heat drying as discussed in Chapter 2. Operations in 1968 and 1969 will serve to reduce this capacity requirement somewhat; but since the exact amount of sludge now in the lagoons is uncertain, this was not considered indetermining later conveyance needs.

Sludge Conditioning Possibilities

It became evident early in the studies for this report that some further consideration should be given to the possibility of sludge concentration. The Sanitary District has conducted or observed extensive experimentation with mechanical and process thickening. These efforts indicate that further concentration will be quite difficult, although lagoon holding has not been evaluated fully as a concentration method.

The potential saving which could be realized in conveyance costs makes further study seem warranted. High concentrations will be available if the Sanitary District decides to empty the existing lagoons, which contain about 1,300,000 tons of dry solids at an average concentration of about 20 percent solids. This emptying would comprise over 30 percent of the dry weight requirement for conveyance, even if extended over a

ten-year period. Thus, blending lagoon sludge with output sludge could provide a higher concentration for conveyance during this period, and it seems likely that improvements of technology by that time might have developed more attractive concentration methods.

As a further factor to be considered, the rigid adherence to a 3.5 percent concentration would eliminate any economic possibility of the barge, rail, or truck conveyance alternatives. Therefore, sludge concentrations of 8.0 percent solids have been assumed to be a future possibility for purposes of comparative estimates using barge, rail, or truck conveyance.

Conveyance Costs

Conveyance system studies have been directed mainly toward the selection of the most suitable Phase 3 project plan based on capital and operating costs for the overall project as well as non-monetary considerations as described in Chapter III and Appendix E. Cost estimates have been made in sufficient detail to provide a valid basis of comparison for alternative plans. They are adequate to generally indicate capital and annual costs for the pipeline system. However, they are not adequate for project financing and do not reflect the most economical selection of individual elements, such as the number of pumping stations. Locations of the principal alternative conveyance systems to each site are shown on Exhibits G-3 through G-6.

Pipeline

Detailed estimates of quantities were computed from preliminary layouts, cross-sections and designs of typical features. The unit prices used include contractor's plant, labor, equipment, materials, general overhead, and profit.

It was assumed that pumping would be a continuous operation (95 percent load factor). For occasional pipeline outages and seasonal

fluctuations of output sludge would be stored in a portion of the existing lagoons. Pipelines would be constructed for the ultimate pumping capacity. The quantities of sludge in the lagoons could be removed using the available pipeline capacity in the initial stages of the project. The ultimate flow values assumed are 2.6 cfs (1.7 mgd) of 3.5 percent sludge (215 dry tons per day) from the Calumet treatment plant and 9.2 cfs (6.0 mgd) of 3.5 percent sludge (845 dry tons per day) from the West-Southwest treatment plant. Pipelines have been sized for velocities of about 3.0 feet per second (fps) to minimize deposition, requiring a 14-inch diameter line from the Calumet plant and a 24-inch diameter line from the West-Southwest plant. A 24-inch diameter line continues from this junction to the project site. The velocity for the major length of the pipeline will be about 3.8 fps at the year 2015 output rate. It was assumed that pipelines would be laid in existing public road and purchased rights-of-way.

Pumping station construction costs including the pumps, buildings, and controls were estimated at \$625 per installed horsepower. It was assumed that one stand-by pump would be installed at each pumping station at one fourth the station capacity. Land for pumping stations was estimated at an average cost of \$5,000 per acre, although the prices may range from \$1,000 to \$10,000 per acre, depending on the station location.

Construction cost estimates include the costs for contingencies, engineering, and interest during construction. Contingencies were assumed at 20 percent of the construction cost; engineering and owners' overhead at 15 percent of the construction and contingencies cost; and interest during construction at 6 percent of the total cost of construction, contingencies, and engineering. A factor of 0.46 times the construction cost results from the additive multiplication of contingencies, engineering, and interest.

A summary of the capital costs of pipeline construction is shown in Table G-1. Combinations of Phase 3 project sites and pipeline alignments resulted in the examination of 25 alternative routes. Selection of the most favorable alignment for a given site alternative was based largely on capital costs.

Barge. Barges are considered as a feasible means of sludge transport only to the Coal City and Essex Sites. Prices for barge hauling were obtained from the Ohio River Company and the Mississippi Valley Barge Company. The capital costs for barge transport include construction of a pipeline from the Calumet Plant to the WSW Plant, a sludge concentrating plant at the WSW plant; sludge loading and unloading stations, and a pipeline to the reclamation site. It was assumed sludge would be concentrated from 3.5 percent solids to 8.0 percent solids.

Barge costs were based on an assumed rental of barges having a capacity of 420,000 gallons. Each barge would carry 140 tons of sludge solids. Eight barges would be required for a daily production of 1060 tons of solids in year 2015. The barges would make a round trip every two days, assuming an unloading station at the Dresden Dam pool.

It was assumed the sludge would be diluted at the sludge unloading station, to the most economical solids concentration and pumped to the on-site distribution system. A summary of the capital costs for barge conveyance of sludge to the two sites is shown in Table G-2.

Table G-1

SUMMARY OF PIPELINE CONVEYANCE CAPITAL COSTSCoal City Site

Pipeline

9.5 miles of 14-in. at	\$105,000/mile	\$ 1,000,000
64.8 miles of 24-in. at	154,000/mile	10,000,000

Pumping Stations

4 stations - 7.7 mgd at 442 ft.	820,000 ea.	3,270,000
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Sub-Total

\$ 14,200,000

Contingencies, Engineering and Interest
during construction at 0.46

6,500,000

Total Capital Cost

\$ 20,700,000Essex Site

Pipeline

9.5 miles of 14-in. at	\$105,000/mile	\$ 1,000,000
57.3 miles of 24-in. at	154,000/mile	8,900,000

Pumping Stations

4 stations - 7.7 mgd at 407 ft.	700,000 ea.	2,800,000
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Sub-Total

\$ 12,700,000

Contingencies, Engineering and Interest
during construction at 0.46

5,800,000

Total Capital Cost

\$ 18,500,000St. Anne Site

Pipeline

9.5 miles of 14-in. at	\$105,000/mile	\$ 1,998,000
65.8 miles of 24-in. at	145,000/mile	9,541,000

Pumping Stations

5 stations - 7.7 mgd at 360 ft.	650,000 ea.	3,250,000
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Sub-Total

\$ 13,500,000

Contingencies, Engineering and Interest
during construction at 0.46

6,200,000

Total Capital Cost

\$ 19,700,000Andres Site

Pipeline

9.5 miles of 14-in. at	\$105,000/mile	\$ 1,998,000
35.4 miles of 24-in. at	154,000/mile	5,452,000

Pumping Stations

3 stations - 7.7 mgd at 428 ft.	780,000 ea.	2,350,000
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Sub-Total

\$ 8,700,000

Contingencies, Engineering and Interest
during construction at 0.46

4,000,000

Total Capital Cost

\$ 12,700,000

Table G-2

SUMMARY OF BARGE CONVEYANCE CAPITAL COSTSCoal City Site

14-in. Pipeline and Pumps from Calumet to WSW	\$2,300,000
Concentration Facilities at WSW	1,700,000
Loading Facilities at WSW	1,400,000
Unloading Station	600,000
30-in. Pipeline and Pumps from Unloading Station to Farm	<u>2,300,000</u>
Sub-Total	\$8,300,000
Contingencies, Engineering and Interest during construction at 0.46	<u>3,800,000</u>
Total	<u>\$12,100,000</u>

Essex Site

14-in. Pipeline and Pumps from Calumet to WSW	\$2,300,000
Concentration Facilities at WSW	1,700,000
Loading Facilities at WSW	1,400,000
Unloading Station	600,000
30-in. Pipeline and Pumps from Unloading Station to Farm	<u>3,000,000</u>
Sub-Total	\$9,000,000
Contingencies, Engineering and Interest during construction at 0.46	<u>4,200,000</u>
Total	<u>\$13,200,000</u>

Rail. Sludge can be conveyed by railroad tank cars to each of the sites considered. To serve the Coal City and Essex sites, sludge would be pumped from the Calumet Plant to the WSW Plant for concentration and loading into tank cars. The Coal City site would be served by the Santa Fe or Gulf, Mobile and Ohio railroad, with a round trip distance from the WSW plant to the site of about eighty miles. The Essex site would be served by the Norfolk and Western or Gulf, Mobile and Ohio railroad with a round trip distance between the WSW Plant and the site of about 70 miles.

To serve the St. Anne and Andres sites by rail, sludge must be pumped from the WSW Plant to the Calumet Plant for concentration and loading into tank cars. The St. Anne site would be served by the Chicago and Eastern Illinois railroad. The round trip distance to the site from the Calumet Plant is about 70 miles. The Andres site would be served by the Illinois Central railroad. The round trip distance to the site from the Calumet Plant is about 45 miles. A five mile pipeline is required from the rail terminal to the project site at Andres, as shown on Exhibit 6.

Equipment and land required for concentration and dilution would be identical to that required for barge transport. Connecting pipeline distances are shorter in the rail scheme than in the barge scheme because the railroad lines are closer to the reclamation sites than is the waterway. For estimation of costs, it was assumed that the tank cars would be rented from the various carriers. Each 24,000 gallon tank car would have a capacity of eight tons of sludge solids in an 8.0 percent concentration, thus 133 rail cars would be required in year 2015 for sludge transport.

Table G-3 is a summary of costs associated with rail transport to each of the sites.

Table G-3

SUMMARY OF RAIL CONVEYANCE CAPITAL COSTS

	<u>Coal City</u>	<u>Essex</u>	<u>St. Anne</u>	<u>Andres</u>
Pipeline and Pumps from Treatment Plant to Concentrators	\$2,300,000	\$2,300,000	\$3,600,000	\$3,600,000
Concentration Facilities	1,700,000	1,700,000	1,700,000	1,700,000
Loading Facilities	1,800,000	1,800,000	1,800,000	1,800,000
Unloading Facilities	<u>200,000</u>	<u>400,000</u>	<u>400,000</u>	<u>200,000</u>
Sub-Total	\$6,000,000	\$6,200,000	\$7,500,000	\$7,300,000
Contingencies, Engi- neering and Interest during Construction at 0.46	<u>2,700,000</u>	<u>2,800,000</u>	<u>3,400,000</u>	<u>3,300,000</u>
TOTAL	\$8,700,000	\$9,000,000	\$10,900,000	\$10,600,000

Truck. Although trucks offer the greatest flexibility for sludge pickup and delivery, their use would be impractical as a long term transport method because of the great number of truck movements and resulting congestion. Approximately 500 trucks per day would be required. This value is based on a truck capacity of 6,000 gallons of eight percent sludge (2 tons of dry solids). The investment costs for

truck transport involve only the terminal facilities which were assumed to be the same as for rail transport. Annual leasing costs were assumed at thirty cents per ton mile. This value is based on a 120 mile round trip.

Annual Costs

Annual costs include interest and repayment of capital costs, power, carrier and driver rentals, and labor and maintenance costs.

Investment Costs. An economic comparison of all sites and conveyance methods (Chapter III) was based on a six percent interest rate. The capital costs were reduced to their equivalent annual costs by assuming a 25 year economic life for equipment and a 50 year economic life for structures.

Power. Power costs were assumed as one cent per kilowatt hour. An overall efficiency of sixty percent was assumed for sludge pumps. Power costs for pumping are shown in Exhibit G-7. The power cost for the mid-year of each decade of the project life was used to determine the average power cost.

Equipment Rental. Costs for rental of barges were obtained from the Ohio River Company and the Mississippi Valley Barge Company. Tank car rental rates and train rental rates were obtained from the Sante Fe Railroad and Norfolk and Western. Truck maintenance and operation costs were based on oil transport costs and sludge trucking costs in Chicago.

Maintenance and Operation Costs. Labor costs were based on prevailing wage rates for similar occupations. Replacement parts and supply costs were assumed as percentages of the capital cost of the equipment or pipeline.

Table G-4 summarizes the annual costs of a pipeline, rail, barge, and truck systems to each of the sites.

Discussion

For the recommended Essex Site, Table G-4 indicates an annual cost advantage for a pipeline system of about 20 percent over rail and barge transport for operation to year 2015. However, the pipeline system also has the highest initial investment cost of the four methods.

Other features besides cost that should be considered in selection of a transport system include reliability and flexibility. A pipeline system offers the greatest reliability because it is underground and not subject to stoppages by strikes and weather conditions. On the other hand, the pipeline may tend to clog requiring periodic cleaning, however, at least some length of pipelines are required in all the methods of transportation considered. Pipelines offer the least flexibility if, for some reason, the Sanitary District wishes to change the location of the land reclamation project after the pipeline is installed. On the basis of flexibility barges, trucks, and trains offer advantage for system flexibility.

Table G-4

ANNUAL COSTS

	<u>Coal City</u>	<u>Essex</u>	<u>St. Anne</u>	<u>Andres</u>
<u>Pipeline Conveyance</u>				
Maintenance and Operation	\$ 525,000	\$ 520,000	\$ 525,000	\$ 520,000
Power	75,000	85,000	85,000	65,000
Investment Costs	<u>1,245,000</u>	<u>1,170,000</u>	<u>1,210,000</u>	<u>760,000</u>
Total	\$1,845,000	\$1,775,000	\$1,820,000	\$1,345,000
<u>Barge Conveyance</u>				
Maintenance and Operation	\$ 340,000	\$ 340,000		
Power	75,000	75,000		
Barge Rental	840,000	840,000		
Investment Costs	<u>770,000</u>	<u>835,000</u>		
Total	2,040,000	2,090,000		
<u>Rail Conveyance</u>				
Maintenance and Operation	\$ 480,000	\$ 480,000	\$ 480,000	\$ 480,000
Tank Car Rental and Operation	270,000	270,000	270,000	270,000
Locomotive Rental and Operation	925,000	840,000	835,000	615,000
Power	60,000	60,000	60,000	60,000
Investment Costs	<u>545,000</u>	<u>565,000</u>	<u>680,000</u>	<u>660,000</u>
Total	\$2,280,000	\$2,215,000	\$2,325,000	\$2,085,000
<u>Truck Conveyance</u>				
Maintenance and Operation	\$11,800,000	\$ 9,415,000	\$11,800,000	\$7,480,000
Investment Cost	<u>545,000</u>	<u>565,000</u>	<u>680,000</u>	<u>660,000</u>
Total (rounded)	\$12,300,000	\$10,000,000	\$12,500,000	\$8,100,000

Recommended Conveyance System

On the basis of all factors involved, the conclusion at the time of preparation of this report is that pipelines are the best conveyance method. However, since an early decision on the method of transport is not critical to completion of the Phase 3 project by its scheduled 1972 date, it is recommended that further study of barge and rail transportation be made. The estimate of costs of these alternatives are considered quite preliminary, and further study of them is believed to be warranted.

The recommended pipeline alignment to the Essex site may be generally described as follows; from the WSW sewage treatment plant south along Central Avenue to State Road, southwest on State Road to Ridgeland Avenue, and then south on Ridgeland Avenue to 127th Street. The 12-inch diameter line from the Calumet sewage treatment plant would proceed along the Calumet-Sag Channel to the intersection at Ridgeland and 127th Street where it would connect to the 24-inch diameter line from the WSW plant. The pipeline would continue south on Ridgeland Avenue to 147th Street, west on 147th Street to State Highway 43 (Oak Park Avenue and Harlem Avenue), south on Highway 43 to a county road in Will County, west on the county road past the Hickory Cemetery to the intersection with U.S. Highway 45, south on Highway 45 to a point about one mile south of the town of Frankfort, and then approximately twenty-two miles southwest cross-country to the Essex site, as shown on Exhibit G-4.

The general route was selected from U.S. Geological Survey maps. Alternative routes were then compared by field inspection and

the final route selected. Within the city and the more populated areas the route was assumed to lie within the public right-of-way. However, from about ten miles south of the junction of the line from the WSW plant with the line from the Calumet Sewage treatment plant, the line would proceed cross-country for about twenty miles, saving about seven miles over following highway routes.

Pipeline routings were selected to avoid construction on major streets to avoid the costs and inconvenience of traffic interruption. Generally, pipelines were routed within public road rights-of-way except in sparsely populated areas where cross country construction would significantly lower the pipeline length. Twenty-five different routings were evaluated for the four sites studied. Since factors other than cost were comparable for the various routings, the least costly route was selected for each transport method. The costs reflect variations in topography, soil conditions, the number of driveways, rail and water crossings, pavement removal and replacement, and right-of-way costs.

Future Studies

Although literature searches, communications with plant superintendents and conversations with Sanitary District personnel have produced sufficient information to compare various methods of conveyance additional work will be required before beginning final design of facilities in the selected project.

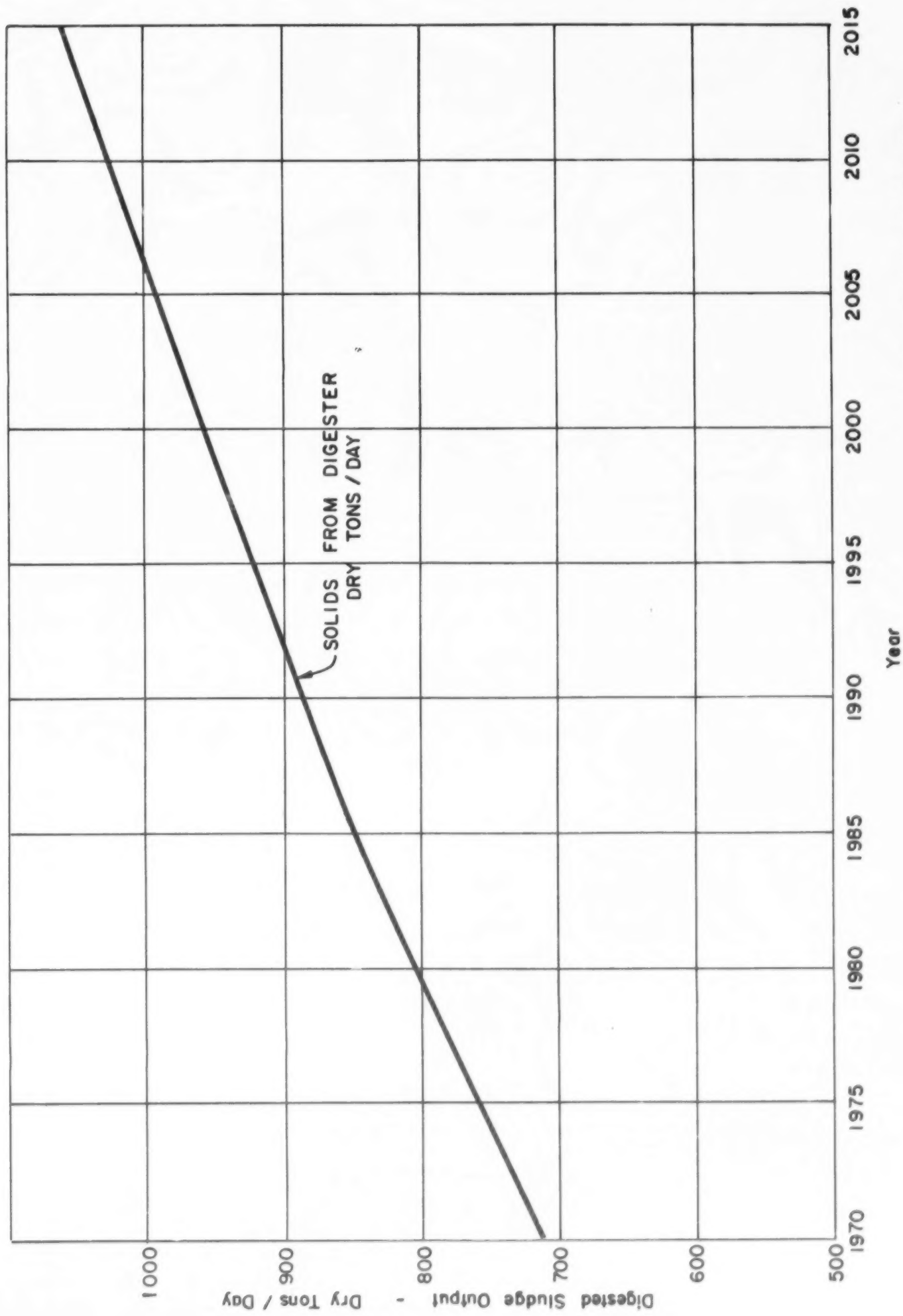
All conveyance methods other than pipelines have assumed that sludge can be concentrated to eight percent solids. This may be impossible to accomplish at a reasonable cost and this aspect should be

investigated first if the Sanitary District chooses a method of transport other than a pipeline. In addition, these studies should investigate the possibility that operation of a pipeline system would be more economical if the concentration was increased to between five and six percent solids. Thus, the velocity-viscosity-concentration relationship should be thoroughly investigated for the digested sludge from the Sanitary District Plants.

Other areas which require further study include:

- (a) Selection of pumping equipment
- (b) Selection of drivers
- (c) Evaluation of lagoon evacuation
- (d) Evaluation of surge suppression equipment.

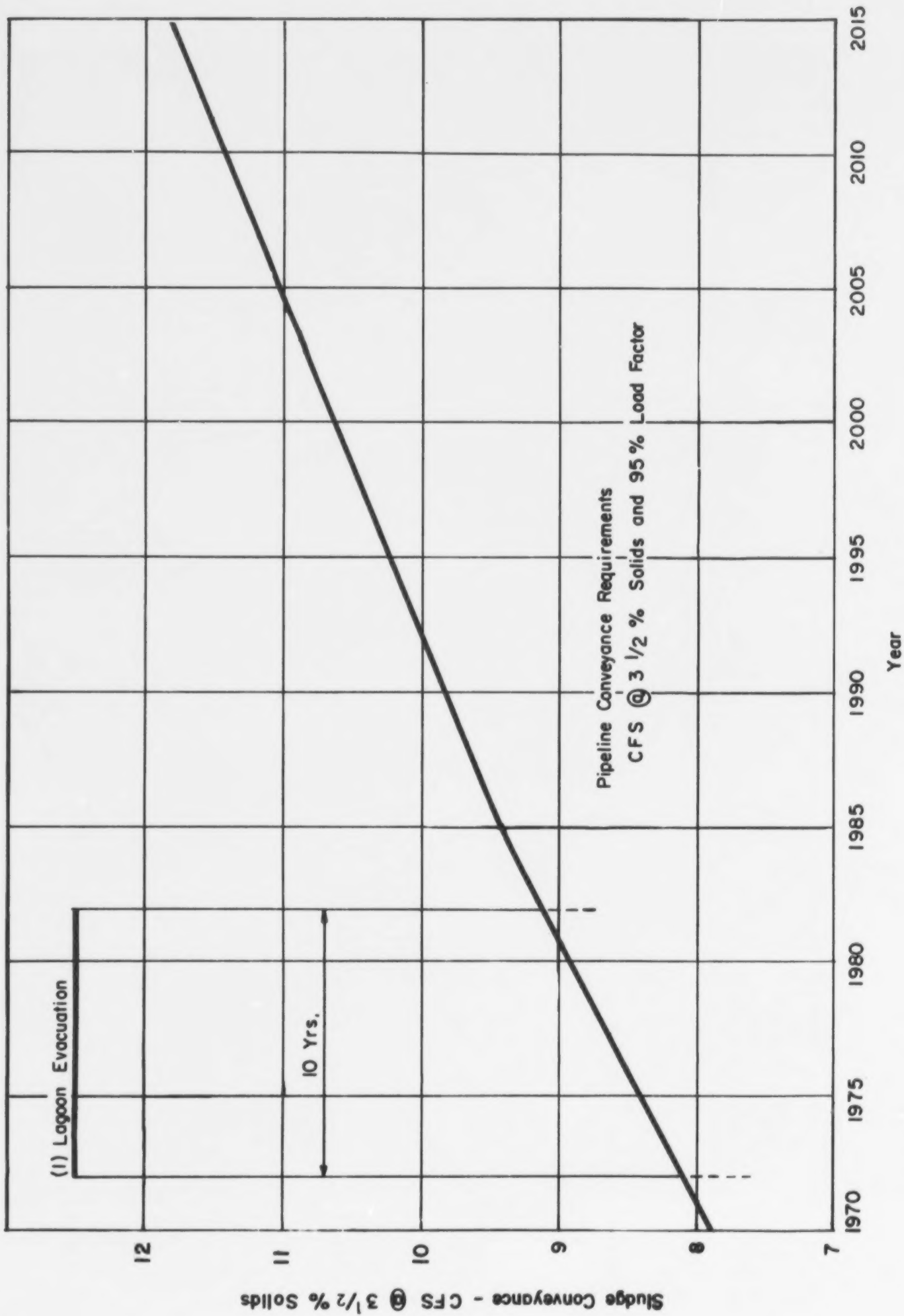
EXHIBIT G-1



LAND RECLAMATION PROJECT

DIGESTED SLUDGE OUTPUT

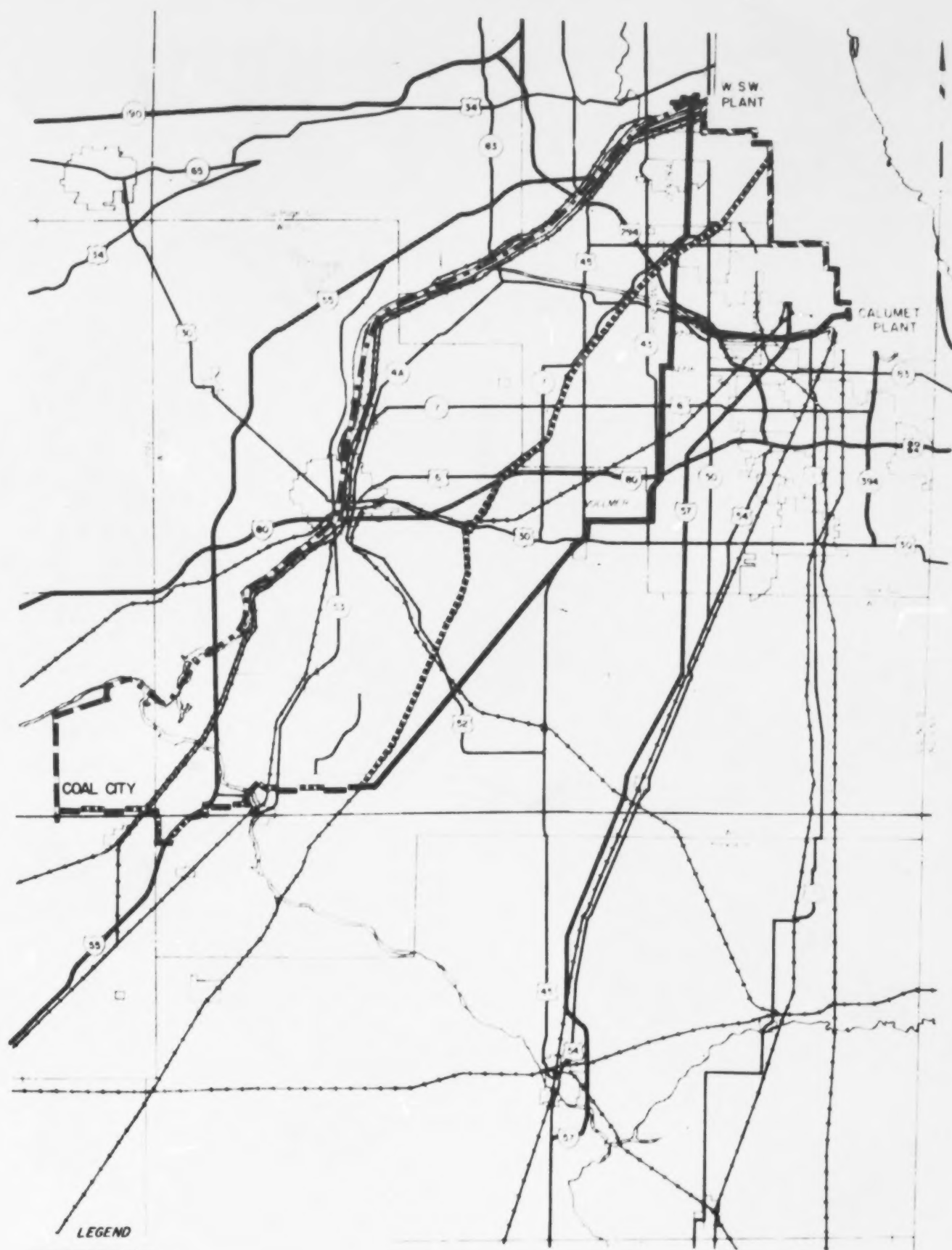
HARZA ENGINEERING COMPANY DWG. NO. 422P26 OCTOBER 1967



LAND RECLAMATION PROJECT

SLUDGE CONVEYANCE REQUIREMENTS

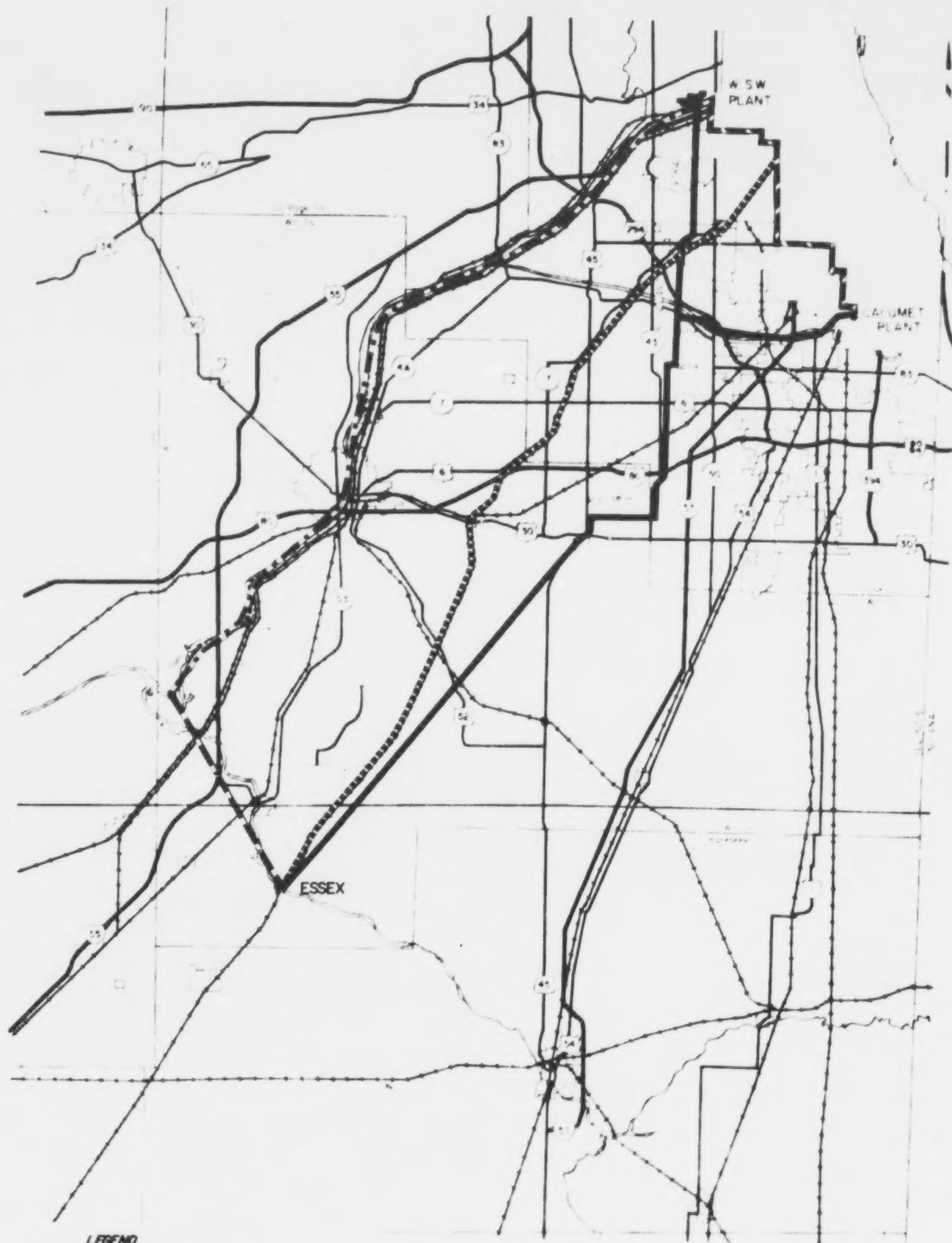
HARZA ENGINEERING COMPANY DWG. NO. 422P27 OCTOBER 1967



LAND RECLAMATION PROJECT

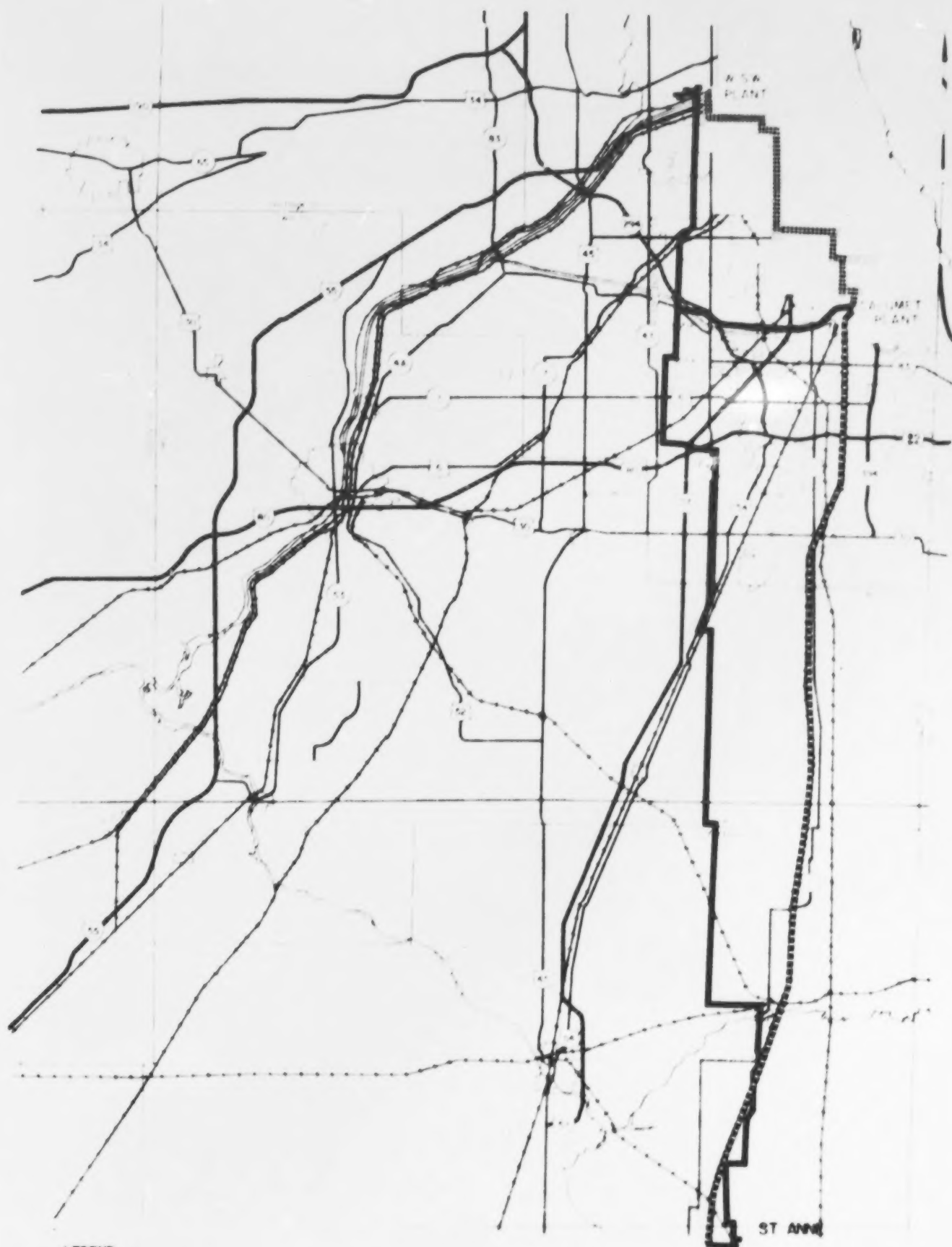
ALTERNATIVE CONVEYANCE ROUTES

COAL CITY SITE



LEGEND
 Solid line Pipeline
 Dashed line Rail pipeline
 Solid line, small dashes Barge pipeline
 Dashed line, small dashes Railroad
 Solid line, large dashes Barge route
 Solid line, large dashes, with dots Pipeline common to barge and rail schemes

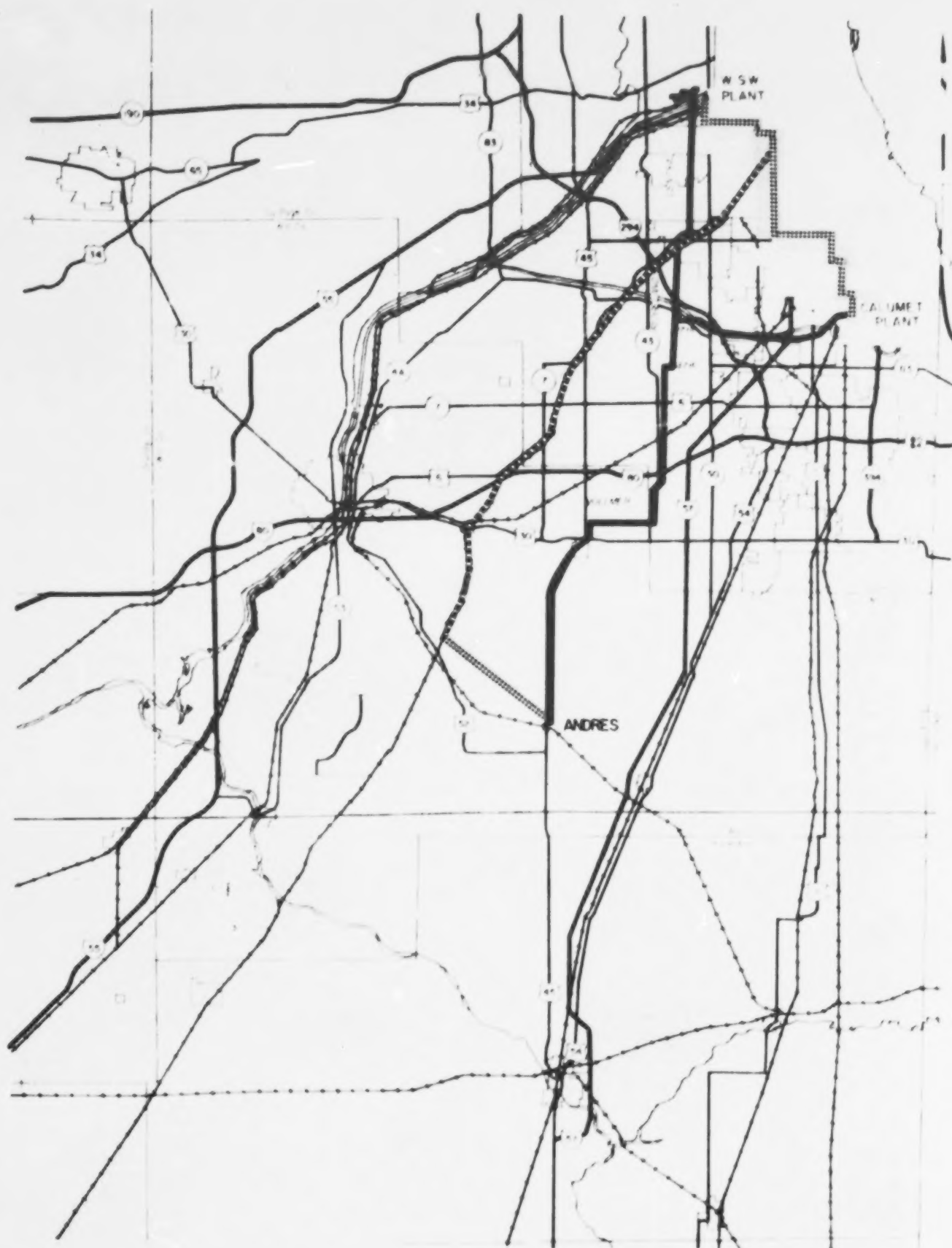
LAND RECLAMATION PROJECT
 ALTERNATIVE CONVEYANCE ROUTES
 ESSEX SITE



LEGEND

Pipeline
 Road
 Railroad

LAND RECLAMATION PROJECT
 ALTERNATIVE CONVEYANCE ROUTES
 ST. ANNE SITE

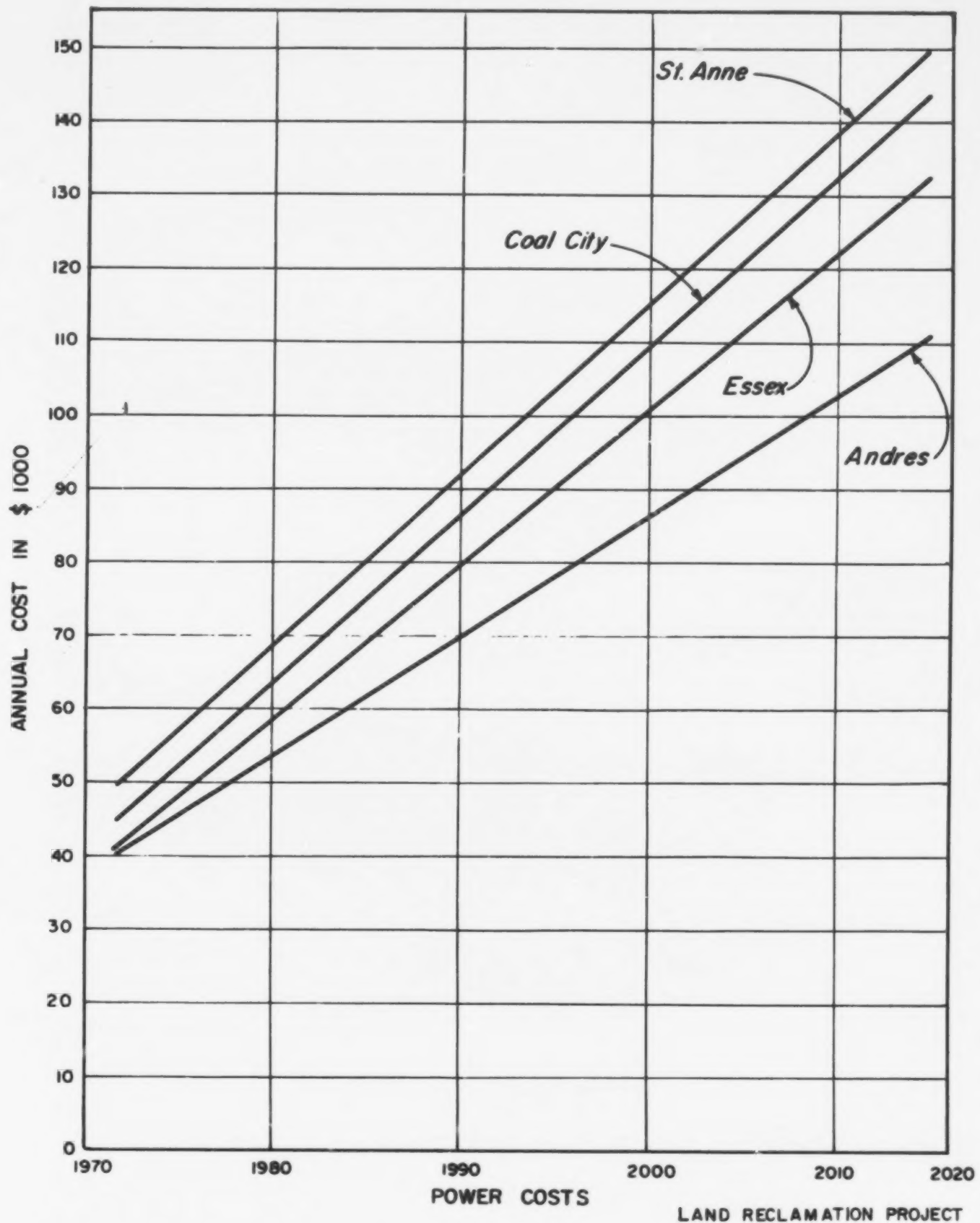


LEGEND

----- Waterway
 (---) --- Road
 ----- Railroad

0 1 2 3 4 5 6 7 8 9 10

LAND RECLAMATION PROJECT
 ALTERNATIVE CONVEYANCE ROUTES
 ANDRES SITE



LAND RECLAMATION PROJECT
ANNUAL POWER COSTS
FOR SLUDGE PUMPING

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Appendix H
COSTS AND BENEFITS

General

Capital and annual cost estimates have been made for the conveyance system and agricultural development features of the land reclamation project. Crop returns and the net returns to the Sanitary District from the agricultural operation have also been estimated. Table H-1 is a summary of capital costs for Phase 3 alternatives, and Table H-2 is a summary of the Phase 3 annual costs and returns.

The costs for the conveyance system and land reclamation system are based on a capacity of 11.8 cubic feet per second (1060 dry tons of sludge per day in year 2015 at 3.5 percent solids concentration). Agricultural development costs are based on a 20 ton per acre per year sludge loading (19,400 net acres and 21,500 gross acres).

In estimating the costs for the land reclamation project the system was broken down into conveyance facilities and agriculture development features. The conveyance system consists of the facilities required to transport the sludge to the site and the agriculture development system consists of the features required to distribute the sludge on the land.

Tinley Park Site

Capital and annual cost estimates have been made for the initial development of the Tinley Park site. These costs are based on trucking

Table H-1

SUMMARY OF LAND RECLAMATION COSTS AND RETURNS

(Capital Costs in \$1,000)

<u>Alternative Transport Methods</u>	<u>SITE</u>			<u>Essex with Irrigation</u>	<u>Essex without Irrigation</u>
	<u>Andres</u>	<u>Coal City</u>	<u>St. Anne</u>		
<u>Pipeline Alternative:</u>					
Transport System	12,600	20,700	19,700	18,500	18,500
Site Development	15,900	20,800	21,300	19,600	14,900
Land Purchase	<u>16,000</u>	<u>14,100</u>	<u>11,300</u>	<u>8,900</u>	<u>8,900</u>
Total Capital Cost (rounded)	45,000	56,000	52,000	47,000	42,000
<u>Rail Alternative:</u>					
Transport System	10,700	8,800	11,000	9,100	9,100
Site Development	15,900	20,800	21,300	19,600	14,900
Land Purchase	<u>16,000</u>	<u>14,100</u>	<u>11,300</u>	<u>8,900</u>	<u>8,900</u>
Total Capital Cost (rounded)	42,000	44,000	43,000	38,000	33,000
<u>Barge Alternative:</u>					
Transport System		12,100		13,200	13,200
Site Development		20,800		19,600	14,900
Land Purchase		<u>14,100</u>		<u>8,900</u>	<u>8,900</u>
Total Capital Cost (rounded)		47,000		42,000	37,000

Table H-2

SUMMARY OF LAND RECLAMATION COSTS AND RETURNS

(Annual Costs in \$1,000)

Alternative Transport Methods	SITE			Essex with Irrigation	Essex without Irrigation
	Andres	Coal City	St. Anne		
<u>Pipeline Alternative:</u>					
Transport System	1,400	1,900	1,900	1,800	1,800
Site Development	<u>2,400</u>	<u>2,800</u>	<u>2,600</u>	<u>2,400</u>	<u>1,900</u>
Subtotal	3,800	4,700	4,500	4,200	3,700
Crop Return <u>1/</u>	<u>837</u>	<u>1,150</u>	<u>1,150</u>	<u>1,150</u>	<u>651</u>
Total Annual Cost (rounded)	3,000	3,500	3,300	3,000	3,000
<u>Rail Alternative:</u>					
Transport System	2,100	2,300	2,400	2,200	2,200
Site Development	<u>2,400</u>	<u>2,800</u>	<u>2,600</u>	<u>2,400</u>	<u>1,900</u>
Subtotal	4,500	5,100	5,000	4,600	4,100
Crop Return <u>1/</u>	<u>837</u>	<u>1,150</u>	<u>1,150</u>	<u>1,150</u>	<u>651</u>
Total Annual Cost (rounded)	3,700	3,900	3,800	3,400	3,400
<u>Barge Alternative:</u>					
Transport System		2,000		2,100	2,100
Site Development		<u>2,800</u>		<u>2,400</u>	<u>1,900</u>
Subtotal		4,800		4,500	4,000
Crop Return <u>1/</u>		<u>1,150</u>		<u>1,150</u>	<u>651</u>
Total Annual Cost (rounded)		3,600		3,300	3,300

1/ Total net return from crops, this figure and totals shown do not reflect any division of return between the Sanitary District and the farmer.

of sludge to the site the first two years. Table H-3 gives the capital costs and annual costs for the initial two periods of operation.

The annual costs are based on amortizing the investment cost over 50 years for all items except the sludge concentration and loading facilities where a two year period was used. An interest rate of six percent was used. This analysis gives a cost per ton to the district of \$16.70 with no returns from agriculture crops included. Including the return of \$73,000 per year gives a cost of \$15.20 per ton of dry solids.

Table H-3

TINLEY PARK CAPITAL AND ANNUAL COSTS

(Dollars)

<u>Item</u>		<u>Capital Cost</u>	<u>Annual Cost</u>
Land		3,880,000	
Agricultural Development	377,000		
Loading Facilities	<u>610,000</u>		
Sub-total	987,000		
Contingencies, Engineering and Interest during Construction	<u>457,000</u>	<u>1,444,000</u>	
Total Investment Cost		5,324,000	659,000
Operation & Maintenance			65,000
Annual Trucking Cost			<u>67,000</u>
Total Annual Cost			791,000

Conveyance System

Cost estimates were prepared for the Coal City and Essex sites using pipeline, barge and rail sludge conveyance systems and for the St. Anne and Andres sites using pipeline and rail sludge conveyance systems. Investment and annual costs for conveyance systems are given in Appendix G.

Agricultural Development System

Investment Costs

Preliminary estimates of agriculture development costs for the four alternative sites are summarized in Table H-4. The data and assumptions on which the estimates are based are presented below. Cost estimates were prepared for the Coal City, Essex, and St. Anne sites assuming irrigation and for the Essex and Andres sites assuming no irrigation.

Detailed estimates of quantities were computed from preliminary layouts, cross-sections and designs of typical features. Basic considerations underlying the estimates are given in Appendix D. The land cost determination is given in Appendix E. The unit prices used include contractor's plant, labor, equipment, materials, general overhead and profit.

The direct costs were increased 20 percent for contingencies, 15 percent for engineering, supervision and overhead and 6 percent for interest during a two year construction period to give the total investment cost. A lump sum of \$100,000 was added to the land costs for legal fees.

The total agricultural capital costs vary from \$1,600 per acre to \$1,100 per acre.

Annual Costs

Estimates of annual costs of the agriculture development are summarized in Table H-5. The costs shown include the operation and maintenance, power, equipment replacement and investment repayment costs.

Table H-4

AGRICULTURAL DEVELOPMENT INVESTMENT COSTS

(Costs in \$1,000)

<u>Item</u>	<u>Site</u>				
	<u>Coal City</u>	<u>Essex</u>	<u>Essex without Irrigation</u>	<u>St. Anne</u>	<u>Andres</u>
Leveling and Grading	1,561	1,765	1,765	1,676	194
Irrigation and Sludge Dis- tribution (Main System)	5,467	4,978	3,803	5,620	3,939
Irrigation Source Develop- ment and Transmission	973	773	---	1,403	---
Drainage (Main System)	348	295	295	280	284
On-Farm Irrigation, Sludge Distribution and Drainage	4,268	4,268	2,995	4,268	4,450
Holding Reservoir and Conservation Areas	220	170	170	270	750
Domestic Water Supply System	1,300	1,100	1,100	1,000	1,200
Operation and Maintenance Building and Equipment	<u>70</u>	<u>70</u>	<u>70</u>	<u>70</u>	<u>70</u>
Sub-total	14,207	13,419	10,198	14,587	10,887
Contingencies, Engineering, and Interest During Constru- ction	<u>6,575</u>	<u>6,210</u>	<u>4,720</u>	<u>6,751</u>	<u>5,039</u>
Sub-total	20,782	19,629	14,918	21,338	15,926
Land Purchase Cost	14,075	8,915	8,915	11,280	16,010
Total Agriculture Develop- ment Cost	34,857	28,544	23,833	32,618	31,936
Rounded Total	34,900	28,500	23,800	32,600	31,900

Table H-5

AGRICULTURE DEVELOPMENT ANNUAL COSTS

(Costs in Dollars)

<u>Item</u>	<u>Site</u>				
	<u>Coal City</u>	<u>Essex</u>	<u>Essex without Irrigation</u>	<u>St. Anne</u>	<u>Andres</u>
<u>Operation</u>					
Personnel	225,000	225,000	225,000	225,000	205,000
Office Expense	20,000	20,000	20,000	20,000	20,000
Power Cost	143,000	146,000	25,000	134,000	37,000
<u>Maintenance</u>					
Personnel	70,000	70,000	70,000	70,000	70,000
Equipment Operation	30,000	30,000	30,000	30,000	30,000
Supplies	10,000	10,000	10,000	10,000	10,000
<u>Replacements</u>					
M&O Building and Equipment	3,300	3,300	3,300	3,300	3,300
Sprinkler Equipment	61,400	61,400	4,000	61,400	4,000
Pumps	18,900	18,600	500	16,900	500
<u>Investment Costs</u>	2,214,000	1,808,000	1,510,000	2,068,000	2,024,000
Total Annual Costs	2,795,600	2,392,300	1,897,800	2,638,600	2,403,800
(Rounded)	2,800,000	2,400,000	1,900,000	2,600,000	2,400,000

The maintenance and operation costs were estimated on the basis of personnel requirements for distribution of sludge, as discussed in Appendix D. In addition, costs were included for office expense, equipment operation and maintenance supplies.

Power costs were estimated at one cent per kilowatt hour, and the number of kilowatt hours was estimated using a pump efficiency of sixty percent.

Equipment replacement costs were estimated using a replacement period of fifteen years for operating and sprinkler equipment and twenty five years for main pumps. An interest rate of six percent was used for all replacement costs.

Annual costs for investment repayment are based on amortization over 50 years at six percent interest.

Agricultural Benefits

Crop Return Summary

Preliminary estimates of net agricultural returns and indirect benefits for the four alternative Phase 3 sites are summarized in Table H-7. Production costs and returns on which the estimates are based are presented below. Estimates of farm costs and returns per acre were prepared for a sandy soil to represent the Coal City, St. Anne, and Essex sites and for a heavy-textured soil for the Andres and Tinley Park sites. Irrigation will not be essential for successful agriculture with sludge application on heavy soil and has not been included for comparison. An estimate was made of net return for the Essex site without irrigation, assuming sludge application only.

Table H-6

SUMMARY OF CROP RETURNS AND BENEFITS

	Phase 3 Sites				
	Andres Site	Coal City Site	St. Anne Site	Essex Site	
				With Irrigation	Without Irrigation
Gross Annual Agricultural Income	\$1,857,000	\$2,593,000	\$2,593,000	\$2,593,000	\$1,474,000
Annual Cost of Production <u>1/</u>	<u>1,020,000</u>	<u>1,443,000</u>	<u>1,443,000</u>	<u>1,443,000</u>	<u>823,000</u>
Net Annual Agricultural Income	\$ 837,000	\$1,150,000	\$1,150,000	\$1,150,000	\$ 651,000
Increase in Net Annual Income due to Project	-48,000	339,000	546,000	581,000	82,000
Increase or Decrease in Indirect Benefits to Community	-39,000	278,000	448,000	476,000	67,000

1/ Includes operator's labor and management, real estate taxes, and other operating costs.

Results of the analysis for the Alternative Phase 3 sites showed a weighted net return per acre with sludge application and irrigation on sandy soil of about \$59 per acre compared to about \$43 on heavy soils without irrigation. Net returns per acre on sandy soil without irrigation were estimated at about \$34 per acre. Net return to the project are estimated at \$1,150,000 for the sandy soil sites with irrigation and \$837,000 on the heavy soil site without irrigation.

The decrease in net agriculture returns anticipated on the Andres site is due primarily to a restricted cropping pattern including a large portion of the area in grass, necessary to handle the required sludge.

These sums are the residual values after deducting from gross farm income (a) farm operating costs, (b) the values of the farmers' labor and management and (c) state and county real estate taxes. The values for farmers' labor and management are based on average return presently obtained by Illinois farmers, and, therefore, not necessarily indicative of the appropriate division of net farm income between the farm operator and District.

Preliminary estimates of net agricultural returns and indirect benefits for the Tinley Park (Phase 2) are summarized in Table H-7. These estimates represent average net returns anticipated during the initial four years of operation. Starting the fifth year, when presumably the Phase 3 site would be in operation, sludge application of only 10 tons per acre would be applied to the net cropped area of 1,650 acres. Net agricultural returns under these conditions are estimated at \$100,000 annually, representing an increase of \$14,000 per year above estimated present net returns.

Table H-7

SUMMARY OF CROP RETURNS AND BENEFITS

Tinley Park Site (Phase 2)

Gross Annual Agricultural Income	\$161,000
Annual Cost of Production	88,000
Net Annual Agricultural Income	73,000
Increase in Net Annual Income Due to Project	-13,000
Increase or Decrease in Indirect Benefits to Community	-11,000

Production Costs and Returns

Costs for producing farm products were obtained from detailed farm accounting records in Illinois for 1965 from the University of Illinois^{1/}. These costs were adjusted for yields projected to 1970. Farm production costs, including costs for farm labor and management are summarized in Table H-8.

Weighted average cost and return were computed on the basis of the assumed cropping patterns required for the sludge application program. These data were extrapolated to each site. The following procedures and adjustments to the basic farm account data were necessary to estimate the costs and returns summarized in Table H-8.

^{1/} Detailed cost report of 36 cooperators in Central and Western Illinois, 1965, Department of Agriculture Economics, University of Illinois, Urbana, Illinois.

(a) Farm labor and management were based on average returns to tenants published in the farm account record by the Illinois Agricultural Experiment Station.

(b) Machinery and power costs for 1965 were adjusted to reflect increased or decreased yields assumed for alternative soil and irrigation situations.

(c) Fertilizer costs were estimated on the basis of a need to add lime and potash in addition to the sludge. Greater quantities were assumed than for normal farming conditions in Illinois because of higher yields anticipated with the project.

(d) Seed and crop expenses were increased about 10 percent to cover increased drying, fuel, insecticides and herbicides and planting rates required with higher yields.

(e) All farm costs including real estate taxes were projected to 1970, the date the project would presumably be in operation.

(f) Irrigation costs were based on automatic "big gun" sprinkler systems, with costs amortized over 50 years at 6 percent.

(g) Gross returns per acre were based on current market prices.

Indirect Benefits

Indirect benefits would result from the project from such aspects as (1) increased production of agricultural products flowing through established channels of trade (2) increased expenditures for farm and family living expenditures from increased incomes made available by the project, and (3) increased land values and, consequently, increased property taxes to local and state governments.

Evidence indicates that average per capita income of most tenant farmers on the alternative sites are relatively low. Project development would provide increased family incomes and higher living standards. To this extent, the project would also provide intangible benefits to the area by meeting national and state goals of increasing income of low-income farmers.

Indirect benefits that could readily be measured in monetary terms were estimated at about 82 percent of the direct agricultural returns. The basis for this estimate was developed from U. S. Bureau of Reclamation procedures and used here only to indicate the magnitude of such benefits from project development. Detailed studies within the local area are required to refine these estimates.

On the basis of this procedure and the yields and cropping patterns assumed, no increase in indirect benefits is anticipated on the Andres site as compared to about \$476,000 annually on the Essex site. A decrease in indirect benefits would result on the Tinley Park site during the first four years of operation after which increases are anticipated due to increased total production under normal agricultural operations. A significant portion of this sum would be increased property taxes accruing to local and state governments from increased land values.

Table H-8

CROP PRODUCTION COSTS AND RETURN

Item	Corn		Soybean		Wheat		Oats		Alfalfa		Grass	
	Heavy Soil Without Irrigation	Sandy Soil With Irrigation	Heavy Soil Without Irrigation	Sandy Soil With Irrigation	Heavy Soil Without Irrigation	Sandy Soil With Irrigation	Heavy Soil Without Irrigation	Sandy Soil With Irrigation	Heavy Soil Without Irrigation	Sandy Soil With Irrigation	Heavy Soil Without Irrigation	Sandy Soil With Irrigation
Crop Yields	120 bu	140 bu	40 bu	45 bu	50 bu	60 bu	80 bu	90 bu	4.0 tons	4.5 tons	2.0 tons	- 1/
Farm Labor and Management	\$24.00	\$28.00	24.00	27.00	17.00	20.00	17.00	20.00	15.00	17.00	\$7.50	-
Machinery and Power	16.75	18.25	14.20	15.40	7.70	8.35	7.70	8.35	2.00	2.20	1.00	-
Fertilizers	8.00	10.00	1.00	1.50	5.50	6.90	1.30	1.70	1.50	1.85	1.25	-
Seed and Crop Expense	8.20	10.20	7.50	9.40	4.35	5.40	3.70	4.60	8.00	8.50	4.00	-
Storage Costs	5.20	5.55	0.50	0.55	-	-	0.35	0.40	-	-	-	-
Interest on Stored Grain	2.95	3.05	2.30	2.50	-	-	1.10	1.20	-	-	-	-
General Farm Expense	4.30	4.30	4.00	4.00	1.80	1.80	2.40	2.40	3.50	3.50	1.75	-
Real Estate Taxes	8.00	10.00	8.00	10.00	8.00	10.00	8.00	10.00	8.00	10.00	4.00	-
Irrigation Costs	-	3.00	-	3.00	-	3.00	-	3.00	-	3.00	-	-
Total	\$77.40	\$92.35	\$61.50	\$73.35	\$44.35	\$55.45	\$41.55	\$51.65	\$38.00	\$46.05	\$19.00	-
Cropping Distribution 2/	33%	50%	22%	25%	5%	5%	5%	5%	14%	10%	21%	5%
Gross Returns Per Acre	150.00	175.00	112.00	126.00	80.00	96.00	60.00	67.50	60.00	67.50	30.00	-
Weighted Gross Returns Per Acre	49.50	87.50	24.65	31.50	4.00	4.80	3.00	3.40	8.40	6.75	6.30	-
Weighted Cost Per Acre	25.54	46.18	13.53	18.34	2.22	2.80	2.08	2.58	5.32	4.60	3.81	-
Weighted Net Return Per Acre	23.96	41.32	11.12	13.16	1.78	2.00	.92	.82	3.08	2.15	2.49	-

1/ Because of the high sludge loadings (200 tons per acre) on the sandy soil grass areas no crop return is expected.

2/ Percentages shown are based on a net area of 19,400 acres.